THE ENGINEERING RECORD

PUBLISHED WEEKLY BY THE

McGraw Publishing Company

MAIN OFFICES:

114 LIBERTY STREET, NEW YORK.

BRANCH OFFICES:

PHILADELPHIA: 929 Chestnut Street.
CHICAGO: 1140 Monadnock Block.
CLEVELAND: Cuyahoga Building.
LONDON OFFICE: Hastings House, Norfolk St., Strand.

SUBSCRIPTION RATES:

United States, Canada, Cuba and Mexico....$3.00 a year.
Foreign subscription .... 6.00 a year.
25 shillings. 25 marks. 31 francs.
Foreign subscriptions may be sent to our London office.

NOTICE TO ADVERTISERS.

Changes in advertisements intended for a particular issue should reach the office of THE ENGINEERING RECORD by 10 A. M. Monday of the week of issue. New advertisements can be received up to noon of Wednesday of the week of issue.

NOTICE TO SUBSCRIBERS.

REMITTANCES.—Remittances should be made by check, New York draft, or money order, in favor of THE ENGINEERING RECORD.

CHANGES OF ADDRESS.—The old address should be given as well as the new, and notice should be received a week in advance of the desired change.

BACK COPIES.—No copies are kept on sale beyond fifteen months from date of issue, except in bound volumes.

Entered at the New York Post-Office as Second Class mail matter.

Copyright, 1906, by the McGraw Publishing Co.

Of this issue of THE ENGINEERING RECORD, 14,000 copies are printed. Total circulation for 1906 to date, 64,000 copies. The total circulation for 1905 was 640,500 copies, an average of 12,317 copies per week.

TABLE OF LEADING ARTICLES.

The Pennsylvania Railroad and New York City... 115
Some Features of Engineering Instruction.......... 115
The Foundations of the Capitol at Albany.......... 116
The Status of Prime Movers.................... 117
The New Water Works of Port Elizabeth, Cape of Good Hope. (Illustrated.).................. 118
Government Contracts: Legal Pitfalls and How to Avoid Them.—VIII. 120
The Construction of Pavements in Chicago....... 122
The Concrete Chimney of the Butte Reduction Co. (Illustrated.) 124
The Estimation of Costs 125
The Sewage Disposal Plant at Downers Grove, Ill. (Illustrated.) 127
Sizes of Return Pipes in Steam-Heating Apparatus. 128
The Construction of the Ritz Hotel, London. (Illustrated) 130
Power Plant Economics. (Illustrated.) 131
Data on Furnace Heating...................... 136
Steel Sheet Piling in a Mining Shaft............ 138
Sewage Disposal Supervision in Illinois......... 138
The Track System of the Philadelphia Subway. (Illustrated.) 139
Book Notes 140
Shrinkage in Road Materials................... 141
Civil Service Questions, Board of Water Supply, New York 141
Street Bounds 142

The Pennsylvania Railroad and New York City.

The enormous extent of the improvements to be made by the Pennsylvania Railroad Co. in the Boroughs of Brooklyn and Queens have been overshadowed by the novelty of the great terminal now under construction in Manhattan. The tunnels under the North and East Rivers are undertakings which seize upon the popular imagination, while the equally important surface lines and yards are overlooked. Yet it is safe to say that the description of the improvements to be made on Long Island by the Pennsylvania interests, prepared by Mr. Cassatt for the authorities of New York City and printed in the Current News Supplement of this journal last week, contains a promise of results as vital to the city as any document that has ever been presented to it. Engineers have always recognized that the Pennsylvania passenger terminal in Manhattan, important as it is, was simply one part of a great plan which would make the city vastly more influential as a railway center, and do much to remove the disadvantages against which its business organizations have been vigorously, if somewhat blindly, objecting for many years. While the article by Mr. Cassatt explains many of the advantages to New York of the projects of his company, the experienced engineer can see from the map that was printed last week the promise of others which were doubtless not mentioned through a desire to avoid the appearance of promising too much. The one great fact, however, that a study of the plans brings out strongly is that the project will make New York grow in manufacturing and commercial directions as nothing else has done since the Erie Canal was opened.

The reason for expecting such a development lies in the extraordinary growth of Brooklyn under the most adverse conditions, which will be removed by the execution of the Pennsylvania Railroad's proposed works. This city has developed without a railroad connection except along the sandy island to the East, which is merely a market garden and summer resort. Car floats can be moored along its water front, thus enabling bulk shipments to be made over lines terminating in New Jersey to portions of the city remote from its business and residential sections. So far as passenger transportation was concerned this great community, one of the largest in the country, was worse off than most villages. Since the incorporation of the city into the municipality of Greater New York as a borough, its transportation facilities have been little changed, and it takes many of the Brooklyn people as long to go from their homes to the Grand Central Station in Manhattan as it takes them to ride to Bridgeport or Peekskill, when they have at last entered their trains. The mere fact that a million people can be forced to live in such an isolated place is evidence that it needs but the presence of good railway facilities, such as the Pennsylvania R. R. Co. offers, to make it far more attractive than at present. It is also manifest that the same lack of transportation advantages which has made the resident of Brooklyn essentially an isolated individual has acted as a handicap to the development of its manufacturing interests. It possesses large works, it is true, but these are of a character that do not require good railway connections; with good connections and the large population of mechanics that the borough affords to draw upon, it is reasonable to expect the erection in Brooklyn and Queens of the same class of establishments which are now going up on the New Jersey flats at numerous places. In fact, such a plan as that of the Pennsylvania Railroad Co. may be expected to check the emigration of large manufacturing establishments from New York to New Jersey.

The company proposes to construct all these improvements, so important to Brooklyn and Queens and so vital to the satisfactory use of the Manhattan terminal, without occupying any public property, save in a few places where it may be desirable to relocate or close unimportant streets in the work of constructing yards. All its lines will be on its own property, and the only permission it requests from the city is to cross a number of streets either over or under their present grade. No grade crossings are planned anywhere and no occupation of streets. Greater benefits were probably never offered to any city in return for the mere right to cross streets. The company does not ask the city to give it any such franchises as are required by street or elevated railroads and there is nothing in its request comparable with the franchise privileges for subway railroads. It is accordingly to be fervently hoped that the authorities will grant the company's petition.

There has been some objection raised to giving the privilege of crossing the streets unless the company agrees to pay large annual sums to the city. It is difficult to believe that such a claim is made in sober earnest. The company is not asking for any valuable franchises. The roads it will build and the yards it will construct are mainly in parts of the two boroughs where land is now of insignificant value, yet even there the company will follow the most advanced railway practice and construct its lines so that they will be without danger to those using the streets they cross. It is true that the privilege of crossing these streets is in a sense a franchise, and as such the company must expect to pay a reasonable sum for it, but the enormous charges that have been mentioned as proper annual payments by the railroad to the city are so preposterous that they cannot be suggested save for the purpose of ascertaining what the company is willing to pay. No railroad company will consider for a moment paying a large sum for the purpose of doing business on its own property, on which it pays regular taxes. No such proposition was ever made before in earnest in any country, and for this reason it is safe to say that it is not the intention of the authorities of New York to attempt to hold up in this way an undertaking which will bring a great increase in prosperity to its people and cause the development of large tracts of land that are at present little better than waste property. It is doubtful if the people of Brooklyn and Queens, to whom these proposed works mean more than anything previously done in all their history, would long tolerate any strangulation of the enterprise by attempts to make the railroad the victim of what would be little better than robbery. The great sums of money that these works will cost must be raised by the sale of the company's securities to investors, and any serious attempt to impose unjust and onerous financial obligations on the company for the mere privilege of running cars over its private property may result in difficulties in the financing of the project that will delay it for years to come. This will be far more serious for the people of the city than for the company.

Some Features of Engineering Instruction.

The interesting letter from Professor Taylor on instruction in railroad economics, which appeared in this journal last week, touches in some respects a much broader educational subject than that to which it is directed. There may be and probably is opportunity for substantial differences of opinion, not only regarding what constitutes "railroad economics," but also as to the topics which should be included in the class-room work on that general subject. Indeed the common use of that title has not yet been subjected to anything like sufficiently concerted definition to give it desirable precision. One of the most important divisions of railroad construction and administration is covered by it, yet there has been no broad agreement among railroad authorities as to its precise meaning or as to what it shall clearly cover in a great railway organization, including the structures and rolling stock. Professor Taylor's own definition is certainly a good one, although it may not be the best, but, admitting that there is such an important subject as railroad economics which engineering schools must teach, the matter demanding the most attentive consideration is the method of giving students the best practicable quality of instruction in this particular field. In the consideration of this matter he does not set forth the exact topics of the course of study involved, but he does insist that the instructor should be qualified by extended experience in railroad affairs, on the ground that there are phases of the subject whose true conception and bearing can be realized only by actual contact with them.

In stating this argument Professor Taylor opens a broad educational question of the highest importance to professional schools. It is but a few years ago that an engineering instructor familiar with practical affairs, not to mention one engaged in practice, was almost unknown. At the present time there are many marked exceptions to the latter part of that observation. The former type of professors was characterized frequently enough by a profound knowledge of the pure science of his profession, but he was not expected to be in touch with practical affairs. Even at the present time there are many trustees or executive officers of engineering schools who persist in the error of strongly objecting to their instructors engaging in active practice. There still survives, fortunately to a decreasing extent, the old fallacy that in some way or other the qualification of an instructor to impart knowledge must be based on his inability to make use of it. One of the longest steps forward taken by modern instructors in professional schools of engineering consists in making the test of a student's knowledge his capacity to use it. Many an engineer who took his educational training twenty or twenty-five years ago is still impressed with the memory of the abstract mathematical demonstrations he was obliged daily to put on the blackboard with scarcely a practical application of them to the real problems of his subsequent work. It was an increasing grind with mathematical formulas, without any material indication of their real significance in the life work of the engineer. In some of the best engineering courses of the country this situation is now essentially reversed. Ample demonstrations of engineering formulas are required to be made, in a rational way, even to a greater extent than in the old days, but recitation exercises consisting largely of memorizing purely mathematical processes are now unknown in the most advanced educational work. Demonstrations are a part of the classroom work, but without the old drudgery of reciting upon them; they are now made in connection with live and real engineering problems and have attached to them all the interests centering about actual incidents of engineering experience. The test of a student's knowledge of them is his capacity to apply the formulas intelligently to precisely the cases which arise in an engineer's work, and there is no more certain or complete criterion of a student's knowledge of his subject. Nor again, is there any more impressive or emphatic exercise of the use of the general principles of engineering science than this exercise in the exact treatment of the fundamental elements of a wide range of engineering problems.

It is to be observed that this distinct advance in engineering instruction, or rather the actual creation of a new field in that instruction, involves an accurate and intimate knowledge of the practice of the profession of civil engineering, and hence an instructor who is qualified to give his students this high grade of instruction must have had the advantage of the practice of his profession, or, indeed, must be engaged in that practice. When, therefore, Professor Taylor insists that an instructor in railroad economics must be a practical railroad man he takes a position which cannot successfully be contested. As a matter of fact he is simply applying the broad principle that a successful engineering instructor must necessarily be a practicing engineer. This is a most rational proposition. It is simply stating that an instructor must be familiar with his subject. The results of an engineer's experience in actual professional work are just as much and just as truly knowledge as his facility in mathematical analysis, which in turn is simply experience acquired with his mathematical text books. One line of knowledge is just as necessary to the well rounded engineering student as the other, and any instructor who is not qualified to impart both kinds of knowledge to his student is by just so much disqualified to do his work as well as it ought to be done. These features of engineering education have not yet been accorded their full significance in the majority of the reputable engineering schools of the country. Those who are responsible for the administration of such institutions not only ought to permit and encourage by every reasonable means their instructors to engage in engineering practice, but such a qualification ought to be exacted to a greater or less extent, not only of every head of a department, but of every instructor engaged in giving instruction in a practical engineering subject. The engineering profession is far too intimately connected with the actualities of human life to be divorced even in its educational training from its active practice. The abstract professor of the former days who used to evolve much from his inner consciousness, aided by his pure mathematics, no longer has a useful field in the engineering school. This broad principle has long been recognized in medical and law schools, where its application is no more important than in the engineering school, and the latter will only attain its true and full professional standing when the engineer-instructor gives the instruction.

The Foundations of the Capitol at Albany.

It has now been several years since the Capitol at Albany attracted attention save as the center of legislative wisdom of the Empire State, but it has at last emerged from its placid condition of apparent security to resume its previous rôle of a structural nightmare. After sinking about $25,000,000 in this building the taxpayers of New York might be warranted in hoping that it was at last completed and fit for occupation for all time, but this expectation has been rudely crushed by recent events. It has been necessary to close the monumental stairway leading up from State Street to the portion of the building reserved mainly for the Assembly. Just what has happened to the building is kept a secret by the authorities, but experienced engineers have made an examination which is said to indicate that some movement of the foundations has thrown such heavy loads on a part of the masonry as to subject it to danger of crushing. It is unfortunate that this has happened at the Assembly end of the building, for, coming after the notorious trouble with the ceiling of the Assembly chamber, the masonry of which has been replaced by papier maché in order to reduce the loads on the walls and piers, it may be thought that this branch of the Legislature is forever condemned to transact business under a sword of Damocles.

The staircase has been the source of considerable trouble in the past, and extensive repairs to it were executed about eighteen years ago. Evidently these were not adequate, however, and if the present authorities are able to do so they should secure an appropriation from the Legislature which will enable a competent engineering commission to make a thorough examination of the building. Mr. Edward P. North, M. Am. Soc. C. E., makes the following comment on the conditions, which indicates how necessary such an examination is: "The difficulty with the Capitol is that it is founded on blue clay, which is without support toward the east. The result is that the clay is fluid under the weight of the building." He adds the further comment that piers carried down to bed rock will prevent the settlement or movement. Anybody who has had any experience in trying to keep heavy buildings in place on a sloping mass of clay will not need to be told that trouble will follow weighting such material if it is free to move sideways. A large structure for manufacturing purposes on the Hudson not far south of Albany has shown a tendency toward extensive travels from this cause, while the trouble in Cincinnati and Cleveland in keeping buildings in place on a mass of unconfined clay is well known. Some important structures in the former city have been giving much trouble lately on account of sliding material under their footings, while the difficulty experienced by the railways along the water front in Cleveland was shown in a number of illustrations printed in this journal a couple of years ago.

As a preliminary step, absolutely essential to the satisfactory solution of the Capitol difficulties, a thorough examination must be made of the materials underlying the building. This must show the slope of the bedrock and the thickness and character of every stratum above it. A thin streak of water-bearing sand below a mass of clay may cause all manner of trouble, yet its location may be difficult to detect. Such an examination will cost considerable money, yet if it is not appropriated the legislators may bring down on their heads many tons of hard and heavy masonry, in addition to the severe criticisms of their constituents.

Until very recently the problem of building foundations on clay was frequently solved with a considerable reliance on Providence as a part of the factor of stability which entered into the design. Buildings were erected on clay which was known to rest on water-bearing sand or fine gravel, because the expense of carrying down deep concrete foundations to the bed rock was very great. Timber piling could not be used in most of these cases because it would be above the water level and was sure to decay in a short time. The only other method of going down to bed rock was by concrete piers put in by means of wells or caissons. More recently, however, the relatively simple concrete pile has come into use and seems to solve such foundation problems in a rational and inexpensive manner.

In constructing foundations in this manner it is important to observe that the concrete piling can be given much higher unit loads than timber piling. Owing to the imperfections of timber piling when driven to refusal, except under careful supervision, engineers have been forced to adopt unit loads which are necessarily low. On the other hand, a well-made concrete pile sunk to bed rock or good substantial gravel is, for all practical purposes, a well-braced column capable of carrying considerably higher loads than a timber pile. The material through which it is driven braces it against lateral distortion, provided this material is not itself likely to move. It is manifest that if a large part of the weight of a building is carried down to bed rock by such piles the remaining weight may be carried by the concrete footings of the walls, for there are very few soils so poor that it is not safe to load them somewhat. Just what proportion of the load should be assigned to the footings in a case of this sort is a matter of judgment, and it thus becomes evident that even though concrete piling offers a new and important constructional resource to the engineer, the sound judgment of foundation conditions which comes only from extensive experience is as necessary as ever for the most economical solution of troublesome problems.

The Status of Prime Movers.

It is safe to say that the majority of engineers engaged in the management of large steam power plants hold much the same views of the relative status of the different prime movers. The progress made during the last year or so in the construction of steam turbines has been along the lines of larger units and of improvements in details so that high temperatures will not seriously affect their operation. Units with a rating of 7,500 h.-p. and an overload capacity of 10,000 h.-p. have been made for stationary practice and even larger units for marine service. In the face of this progress, however, some engineers of critical judgment have still preferred to pin their faith to the reciprocating engine, as is shown by the fact that two large Manhattan-type engines were recently ordered from the Allis-Chalmers Co. The demand for smaller reciprocating engines, say, from 2,000 h.-p. down, shows no evidence of competition from the turbine. So far as economy is concerned it is difficult to distinguish any marked advantage in the performance of either type. It is not fair to judge a type from one or two isolated examples, and the collected data concerning both types show essentially equal results. The high rotative speed of the turbine is a manifest advantage in enabling its size to be kept down, but, on the other hand, its auxiliary apparatus is large and sometimes difficult to place. The turbine has one advantage which operating engineers will concede, the uniform rotative speed, but the importance of this advantage is a matter on which the builders of reciprocating engines make some strong arguments. The large gas engine is still considered in the experimental stage in this country, although the experience abroad indicates that this feeling is more one of conservatism than of any lack of confidence in these prime movers. Their irregularity of torque will doubtless prove less important for most purposes than has been anticipated, particularly with the introduction of several cylinders and heavy flywheels, while lack of overload capacity will not be a serious matter as soon as engineers appreciate that the gas engine will not run overloaded and make their plans accordingly.

The above-stated views express the general opinion of engineers who have been following the recent development of power plant equipment, but now comes the iconoclastic paper by Mr. Henry G. Stott, superintendent of motive power of the Interborough Rapid Transit Co., entirely controverting some of these opinions. The paper is printed in full elsewhere in this issue, and it is only fair to the author to add that the reprint is made from an advance copy subject to revision and may contain some errors. The author estimates that a steam turbine plant has an inherent economy 20 per cent. better than that of the best type of reciprocating-engine plant, not so much on account of higher thermal efficiency as for other reasons which are stated in detail. He also believes that the present type of steam power plant can be improved in efficiency about 25 per cent. by the use of more scientific methods in the boiler room, by the use of superheat, and by running the present types of reciprocating engines with higher pressures and adding a steam turbine in the exhaust line between the engine and condenser. At the same time that the efficiency is increased by these means, it is believed that the output of the plant can be increased to double its present amount at a comparatively small cost for turbines and boilers.

Not satisfied with making such strong claims, which are backed up with very convincing arguments, Mr. Stott suggests an entirely new power-plant equipment which will give better results, he believes, both in efficiency and reliability, than the steam-turbine plant and this at a far lower cost per kilowatt-hour. This is a combination of gas engines and steam turbines in the same plant. A steam turbine unit can be built which will take care of 100 per cent. overload for a few seconds, and as the load fluctuations in any plant will probably not average more than 25 per cent., with a maximum of 50 per cent. for a few seconds, Mr. Stott believes that in a plant designed to operate normally with 50 per cent. of its capacity in gas engines and 50 per cent. in steam turbines, any variations in load likely to arise in practice can be taken care of. The reasons for expecting high economy in such a plant are stated in detail in the paper and the fact that the suggestion comes from an engineer of such standing is enough to lend the idea considerable weight.

This important paper bears the mark of so much thought and contains so many statements that must be carefully weighed before they are accepted as the complete data on their respective subjects, that it is wholly impracticable to discuss it in detail without careful study. In many respects it is the most important contribution to power plant engineering made by an American engineer for many years. It is high time for our ideas on the various factors which enter into power plant performance to be set in order, and this paper will be a great help in accomplishing such an end. While its assertions may be looked upon as too ambitious for accomplishment by the apparatus and methods of to-day they are very interesting as pointing out possible lines of future development.

Notes and Comments.

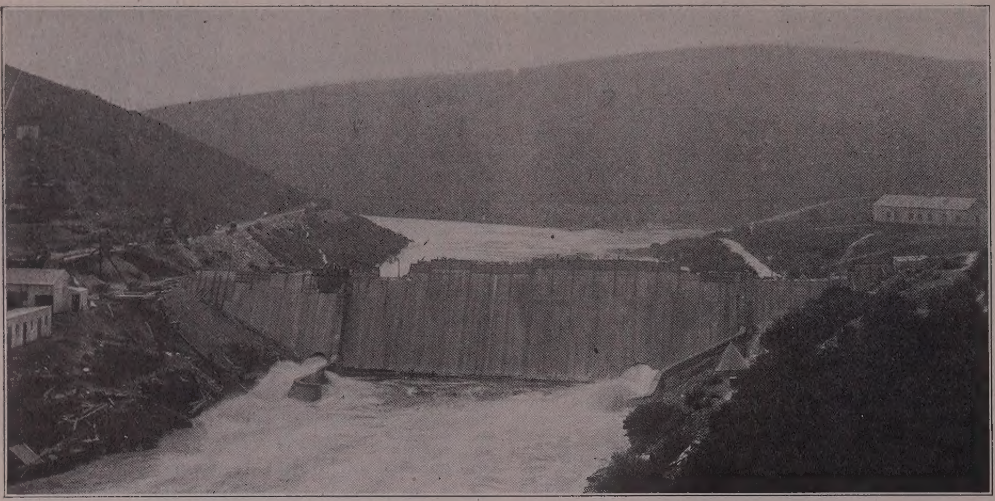
A Flywheel Accident occurred in the works of the Morgan Engineering Co., of Alliance, about a month ago, when a wheel 16 ft. in diameter weighing about 14 tons, burst under unusual conditions. A rope drive is used with this engine, and the rope broke, one end striking the governor and putting it out of commission. The engineer thought it too dangerous to go near the throttle so immediately started to shut off steam at the boilers. Before he could do so the engine ran away, being unloaded and without any governor, and the wheel burst in consequence. Fortunately the plant was shut down only 3½ hours, for the engine drove one end of a jack shaft and a duplicate engine in reserve at the other end of the shaft was soon put in service.

A Premature Blast in the outlet tunnel of the Shoshone dam, which is being built by the Reclamation Service near Cody, Wyo., killed a couple of men about six weeks ago. These two were the only men in the tunnel at the time or the loss of life would have been much greater. The noise of the explosion attracted the attention of a boiler fireman in the vicinity, who procured help and entered the tunnel, finding the body of one of the men. The body of the second man was not discovered until the next day, when it was found in a river many feet from the mouth of the tunnel. From all the evidence that could be found it seems that the men were engaged in loading a hole with dynamite, when it was prematurely exploded. No blame appears to attach to the contractor or the government engineers in direct charge of the work.

A Concrete Conduit 5 ft. 3 in. in diameter and 11,500 ft. long has been built at Cambridge, Mass., as a part of the new aqueduct of the water-works of that city. Unless obstructed it can never be filled, and as there are consequently no severe strains upon it reinforcement has not been employed save in a crossing under some railway tracks. The concrete is 6 in. thick on the bottom, 13 in. at the sides at the spring line of the arch and 7 in. on top. Steel centers were used. The concrete was formed of one part of Helderberg Portland cement, two and a half parts of sand and five parts of screened gravel, and cost $7.23 per cubic yard in place, including all charges except lumber, of which but little was used, superintendence and engineering. The work was done under the direction of Mr. Freeman C. Coffin, consulting engineer, and proved entirely tight when tested.

Road Improvements under State aid in New York are held back by lack of funds for the State's part of the construction. One half of the necessary sum for the improvement of 2,101 miles has been provided by the counties within which the several roads are located. The State has appropriated up to Jan. 1 of this year, sufficient money to provide for its one-half of the cost of 704 miles, leaving 1,397 miles to be provided for. Of the 704 miles, 573 are completed and in use and about 119 miles are now under contract; these will be finished this year together with about 12 miles for which contracts have not yet been made. The 1,397 miles will be taken up for construction as soon as sufficient funds are provided by the legislature. Petitions for the improvement of 7,425 miles of roads have been received. It will thus be seen that the new road law authorizing a State debt of not over $50,000,000 for road improvements will be a great help in aiding rapid progress in such work. It will be a misfortune if the legislature does not act favorably on a large number of the applications which will come before it for assistance in building better highways in many parts of the State. Such highways are much needed and their effect in attracting people to sections where they exist is too thoroughly established to be successfully controverted.

The Gladiatorial Races in Florida have been very tame this year, as nobody has been killed and the accidents have been trifling. The fact that a couple of motor cars have been driven at a rate something better than two miles a minute is of no consequence to anybody save the sensation lovers and the newly rich, whose annual visit to the Florida beach to see men risk their lives reminds the calm observer of the Biblical account of the herd of swine which, when possessed by devils, ran down to the sea. Just what value to the automobile industry there can be in such shows is incomprehensible; they are on a par with the exhibit of two locomotives allowed to run into each other for the delectation of a country fair, although these races are far more dangerous. While it is true that the trials of speed are in a measure a test of the ability of manufacturers to build high-grade machinery, they are more of a test of the nerve of the driver, and as such are distinctly brutal. Although the automobile industry is steadily winning a position of permanent importance in the country, its fringes will always be smirched with such performances as that in Florida, just as the six-day bicycle races cling to the bicycle industry. The progress in motor car construction which is of real worth is not along the line of freak cars, however, but in the direction of vehicles which are durable, of reasonable cost, and fitted for the every-day uses of men and women who can derive pleasure from other exhibitions than those on a level with the shows of the Roman Empire. A contractor's cart driven by its own power, for example, is a development worth considering. The trouble with the motor car business in the past has been the failure to recognize the demand for cars which people in moderate circumstances can afford to buy.



The Sand River Dam During the Flood of September, 1905.

THE NEW WATER WORKS OF PORT ELIZABETH, CAPE OF GOOD HOPE.

There is now in course of construction for the city of Port Elizabeth, Cape of Good Hope, a $1,800,000 system of water-works comprising two reservoirs and a long pipe line. The works are being executed under the direction of Mr. W. Ingham, Assoc. M. Inst. C. E., the city's hydraulic engineer, who has supplied the following information concerning them.

The Sand River reservoir has a capacity of 219,600,000 gal. The water backs up the Sand and Palmiet Rivers for a distance of half a mile, making the total length of the reservoir about one mile, and the total area 40.10 acres. The Sand and Palmiet catchment area is 20.41 square miles.

The dam wall is 50 ft. high from the old river bed to the overflow level and 55 ft. to top of parapet wall. It is built of cyclopean rubble, or concrete with large stones called plums embedded in it. The wall contains 9,000 cu. yd. of material, including large rocks or plums.

The concrete is composed of 5½ parts stone broken to pass a 1¼-in. ring, 1⅓ part sand and 1 part Portland cement. The quartzite has been tested for compression and stands from 1,418 to 1,958 tons per square foot before crushing takes place, and weighs 167 lb. per cubic foot. The concrete as placed in the dam weighs 146 lb., giving an average weight of 150 lb. per cubic foot for the whole dam. All stone was carefully selected before being broken, and only good, sound, clean stone used; the displacers or plums were all washed and cleaned with steel brushes before placing in position, and all sand sieved and washed before mixing. To give additional strength to the dam and prevent cracking a large number of iron rods and tram-rails have been embedded in the concrete. The dam has been designed so that all stresses fall within the middle third.

During construction the river was passed through two culverts of horse-shoe section, 8 ft. in diameter, and on one occasion, in last September, these culverts discharged at the rate of 2,821,000,000 gal. per day, the velocity of the water being about 49 ft. per second, and the depth in front of the dam 32 ft. To give some idea of the force of water flowing through such a limited space, Mr. Ingham says that stones weighing nearly two tons were knocked about as if they were pebbles and left lying from 20 to 30 yards away from their original position. One of the accompanying illustrations shows the dam at the time of the flood; 24 in. of rain fell during this month.

The length of the dam at overflow level is 390 ft., and the overflow is 151 ft. long. The bottom width of the dam is 38 ft., and the top is rounded off to form the overflow weir. The dam is well tied into the base rock, which is hard shale, lying vertical. Three small springs were brought up in pipes within the concrete, and if the water does not rise when the reservoir is filled they will be plugged up. To give additional security and stop any chance of sliding, a large number of 1-in. square iron rods were let into the solid rock and carried up 12 in. into the dam.

At the rear of the dam is a large measuring basin, with a 100-ft. weir, for measuring the quantity of water passing over or through the dam. The water is gauged by a Hutchinson discharge recorder, and every drop passing down the river will be measured and recorded, so that if any time it is found necessary to obtain a greater supply for Port Elizabeth these figures will prove if it is advisable to build another reservoir in this valley.

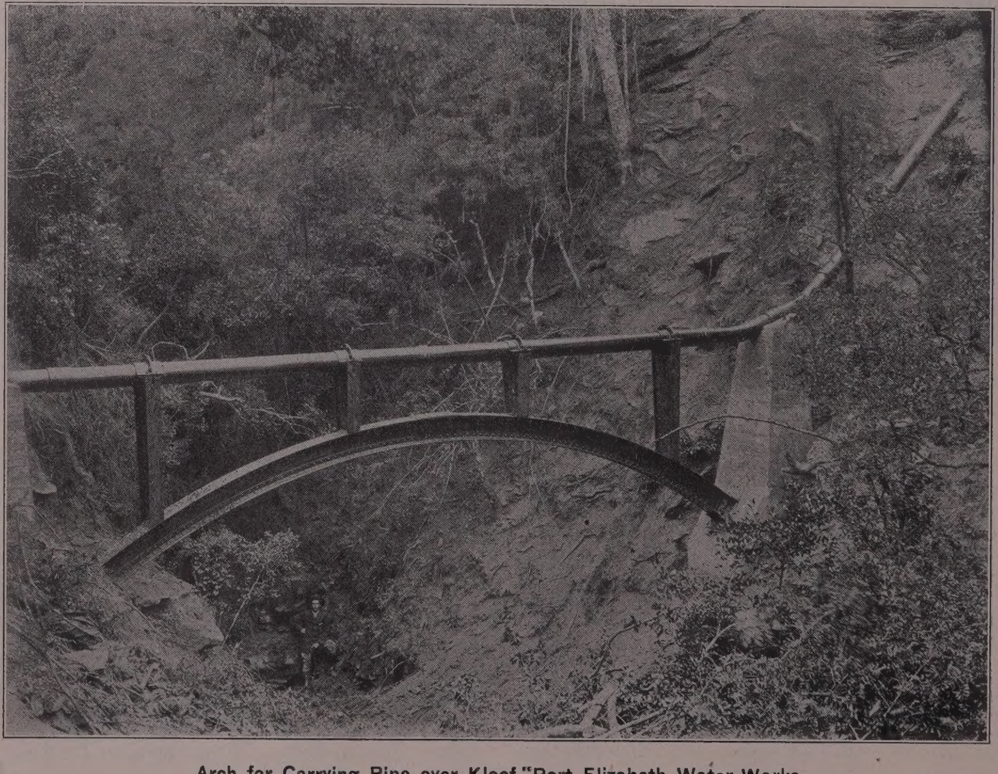
The washout pipe, which is 3 ft. in diameter, has its mouth covered with a gun metal screen and empties into the gauging basin. The discharge through the washout is controlled by a 36-in. sluice valve with roller bearings, and can be easily opened by one man. An 18-in. mild steel pipe takes the water from the reservoir for town use, and the quantity passing is gauged by a Venturi meter with a range of discharge of from 273,000 to 3,744,000 gal. per day. There are three draw-offs at different levels, controlled by 18-in. sluice valves in the tower and ordinary sliding valves in the reservoir. Should it be found necessary to draw off at a lower level at any future time, a syphon pipe, which is provided, can be attached to the bottom draw-off pipe.

To add a little to the architectural features of the dam and break the length somewhat, a valve house has been erected at the south end of the overflow weir, and the top of the parapet wall has an overhanging cap or cornice supported on concrete brackets. The walls of the basin have been continued up the down-stream face of the dam to the full height of the parapet wall, and these side or wing walls will guide the overflowing water into the basin below. The right bank culvert, which is terminated with a portal, is only blocked up for the first 9 ft., so that all valves and pipes can be examined and repaired.

The Venturi meter and Hutchinson weir recorder are housed in a building at the south corner of the basin wall. A caretaker's house, built of concrete and containing six rooms, is built on the side of the hill overlooking the reservoir. The filter plant and house will be erected about 150 yards below the dam.

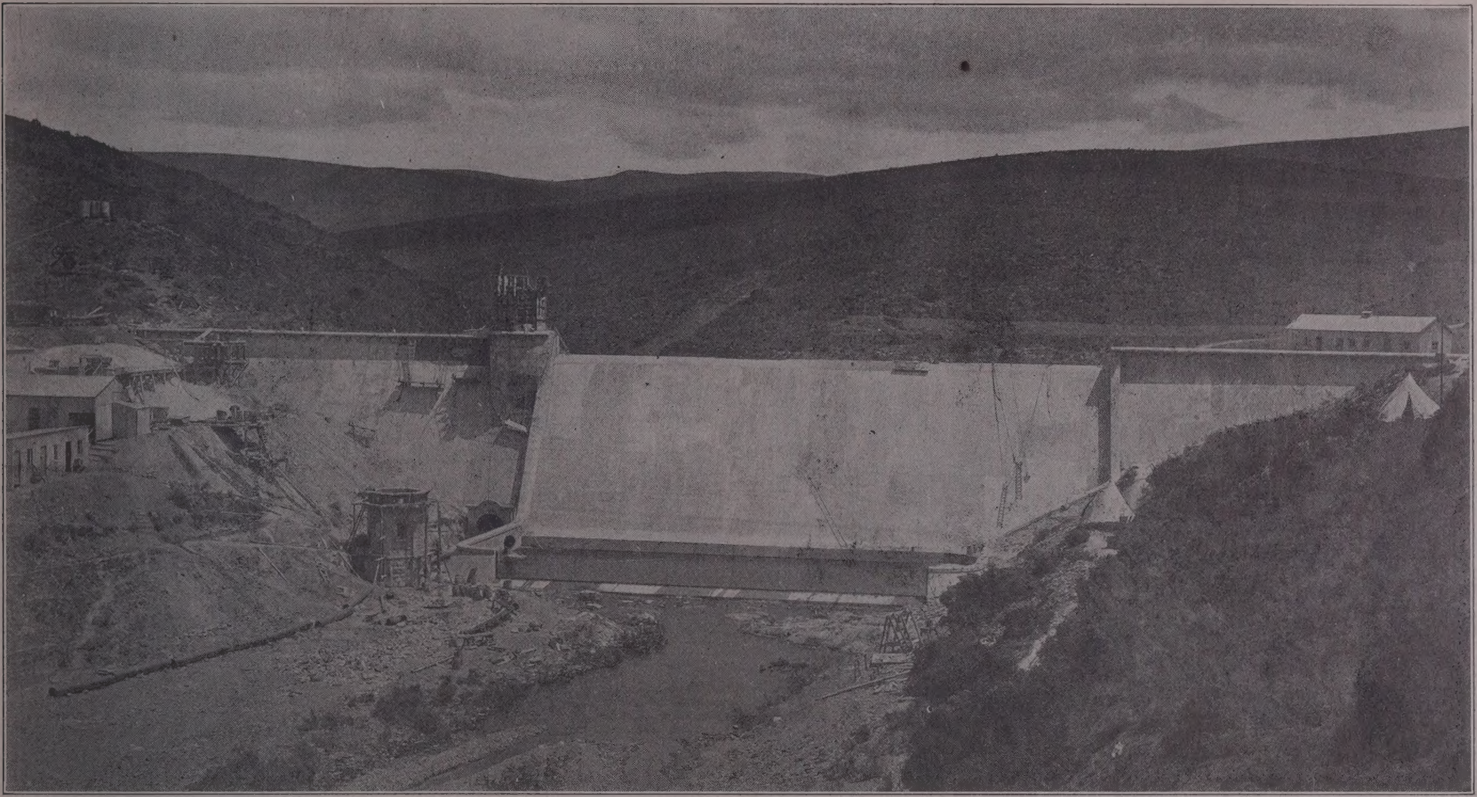
The bed of the river is being cleared of vegetable matter as far as possible, and the sides, under water, are being ploughed and cleaned. Every care has been taken to construct a good and inexpensive dam, but no money has been saved at the expense of solidity and soundness of work.

At the quarry there is a 10-h.-p. portable engine for burning either wood or coal, working at a pressure of 100 lb. per square inch and 140 r.p.m. This engine drives a 16x9-in. Baxter stone crusher, capable of crushing eight tons of quartzite to a 1¼-in. gauge per hour. At the entrance to the quarry is a locomotive steam crane, running on a standard gauge railway, which will lift three tons at 20 ft. radius. From the quarry, and skirting the Palmiet River is a 2-ft. gauge railway 1½ miles long, for conveying broken



Arch for Carrying Pipe over Kloof, Port Elizabeth Water-Works stone and displacers to the dam. A petrol locomotive engine is used for taking the cars to and from the quarry, and the cars have a capacity of 18 cu. ft. Adjoining the quarry and on the same side of the river, is a magazine for storing explosives and a blacksmith's shop. On the opposite bank the workmen's quarters are situated.

When the broken stone arrives at the dam it is tipped into a hopper and the proper quantity of sand added. The mixture then gravitates to a 9 cu. ft. tub, which forms part of the concrete mixer; the cement also gravitates into the tub, while the stone and sand is being admitted. The tub is then lifted automatically and tipped into a hopper which communicates directly with the mixing cylinder, where the correct quantity of water is added, and the mixing commences. This machine is capable of turning out 15 cu. yd. per hour. When the mixing is completed in the cylinder or drum, a sliding door is opened while the machine is at work, and the concrete drops into a skip or bucket placed underneath. The skip is mounted loosely on a trolley and is run from the mixer on a short length of tramline to a point immediately under the Blondin or aerial cableway, and the concrete can then be delivered by the cableway to any portion of the dam wall, as the head and tail gear are movable on five lines of rails. The Blondin is capable of handling 12½ cu. yd. per hour to any part of the dam.



View of the Nearly Completed Sand River Dam of the Port Elizabeth Water-Works.

The cement was specified to stand a tensile strength of 400 lb. per square inch at seven days and 500 lb. at one month. The specification was a strict one and somewhat similar to the specification recently issued by the Engineering Standards Committee, and known as the British Standard Specification for Portland Cement. The tests have turned out well, with the exception of the first batch of 200 tons, which was rejected. A record of all tests carried out in England and at Sand River is entered up for reference in the office.

The cement is stored in a galvanized iron building, which holds 60 tons on the top and 40 tons on the lower floor; the cement is taken out of the barrels on the upper floor and emptied into a chute which enters the cooling machine, where the cement is cleaned of all deleterious matter and allowed to fall a distance of 6 ft. in a fine spray. From the cooling floor the cement is sent down another chute in measured quantities and emptied direct into the 9 cu. ft. tub attached to the concrete mixer.

The machine shop contains a 23 b.h.p. Campbell oil engine for driving the concrete mixer, cement cooler, saw bench, 7-in. lathe, and drilling machine. On the right bank of the river there are the material store, oil and paint store, and the mechanics' quarters. Opposite the above, on the left bank of the river, are the engineer's offices, blacksmiths' shop, stables, workmen's quarters, and a cement testing room. A telephone has been erected from Sand River to the town hall at Port Elizabeth, and all offices and stores are connected.

The Bulk River dam will be 76 ft. high from the river bed to the overflow level, contain 144,000,000 gal. and back the stream up for a distance of four-fifths of a mile. Its up-stream face will be built of concrete blocks, while the downstream face will be of quartzite obtained on the site. This dam will be curved upstream to a radius of 300 ft. The surrounding scenery is very fine and picturesque, and the dam has been so designed that it will add to the beauty of the locality. The catchment area of the reservoir is 11.22 square miles.

The pipe line from Bulk River dam to Green Bushes break-pressure tank is 17¾ miles in length, or about 45 per cent. of the total length of the whole pipe line. This section comprises a series of mild steel pipes of different diameters, consisting of 2 miles of 9-in., 7½ miles of 15¾-in., 6⅕ miles of 17¼-in. and 2½ miles of 13-in. The 9-in. is a branch line from Bulk River to the main line, and joins it near the north end of the tunnel; the other three sizes are designed according to the various gradients, bearing in mind the question of nesting, the saving in freight due to nesting alone being $25,000 to $30,000. The 9-in. pipe will deliver 900,000 gal. when new and 600,000 gal. when encrusted, while the main pipes will deliver 2,700,000 gal. when new and 1,800,000 gal. when incrusted. The first seven miles of this section is through very rough and inaccessible country, requiring 22 kloof crossings up to 90 ft. long, three river crossings, the largest of 420 ft., and a 6x4-ft. tunnel 1,132 ft. long.

Every precaution has been taken to obtain good pipes, and the tests have been rather severe. The steel is Siemen's Martin mild steel, made by the open hearth process. The physical tests prescribed were: Tensile strength, 24 to 27 tons per square inch; limit of elasticity, 13 tons; elongation, 16 per cent. on an 8-in. length, with a minimum reduction of area of 50 per cent. A 5 per cent. variation was allowed in rolling the plates. The chemical tests, made from each melt, had to be within 0.05 per cent. phosphorus, 0.03 per cent. sulphur, 0.50 per cent. manganese, 0.03 per cent. silicon, and 0.15 per cent. carbon. Bending and welding tests were also specified, and all pipes were tested before dipping to 400 lb. per square inch. The pipes received two coats of coating composition instead of one, as usually given. Over 2,000 tons of pipes, valves, bridges, etc., have been used in the construction of this section.

The quantity of water passing through the Bulk River main will be gauged by a Venturi meter. A filter plant is fixed directly on the line, and is known as Candy's automatic air compressing and aerating polarite filter. These filters were substituted for the sand filters originally proposed. The original cost is much less than the latter type, and another most important point is that the maintenance and working expenses are only $275 per annum as compared with $2,050 per annum for sand filtration. The cleansing of the filter is carried out by simply reversing the flow of water, and all detrimental matter is washed away and run to waste. The bacterial purification by this system is stated to be very high, and the water is aerated in its passage through the filter.

Government Contracts: Legal Pitfalls and How to Avoid Them.—VIII.

By George A. and William B. King, Members of the Bar of the Court of Claims.

Penalties. and Forfeitures.—Most government contracts contain a time limit and many of them provide a penalty for every day's delay in completion beyond such limit. An instance of this is found in one of the Navy Department's dry dock contracts, as follows: "In case the completion of the dry dock, its accessories and appurtenances, shall be delayed beyond the said period of thirty calendar months, deductions of $100 per day during the first three months following the expiration of said period, and of $200 per day for each and every day beyond the expiration of the said three months, shall be made from the contract price of said dry dock as liquidated damages."

The following is taken from a contract of the Army Engineer Corps: "In case of failure to complete and deliver either the boat or hull at the designated place within the time specified, the contractor shall forfeit the sum of $40 per day for each day's delay beyond that time, the amount to be deducted from the final payment under the contract." These provisions in terms impose the amount named as an absolute penalty without reference to whether the government has sustained actual damages by the delay.

In some contracts a forfeiture is declared of all retained percentages if the progress of the work is not satisfactory to the government. After providing for notice to the contractor from the government, they say somewhat as follows:

"And upon the giving of such notice all money or reserved percentage due or to become due to the party or parties of the second part by reason of this contract shall be and become forfeited to the United States."

This also creates a penalty of a fixed sum, having no definite relation to the actual loss.

Penalties Not Enforced.—The courts are very loath to enforce provisions of this kind literally. The tendency of the decisions is to declare that the amount of the penalty is the limit of liability and to award damages only to the extent of the actual loss of the party to whom the obligation is given.

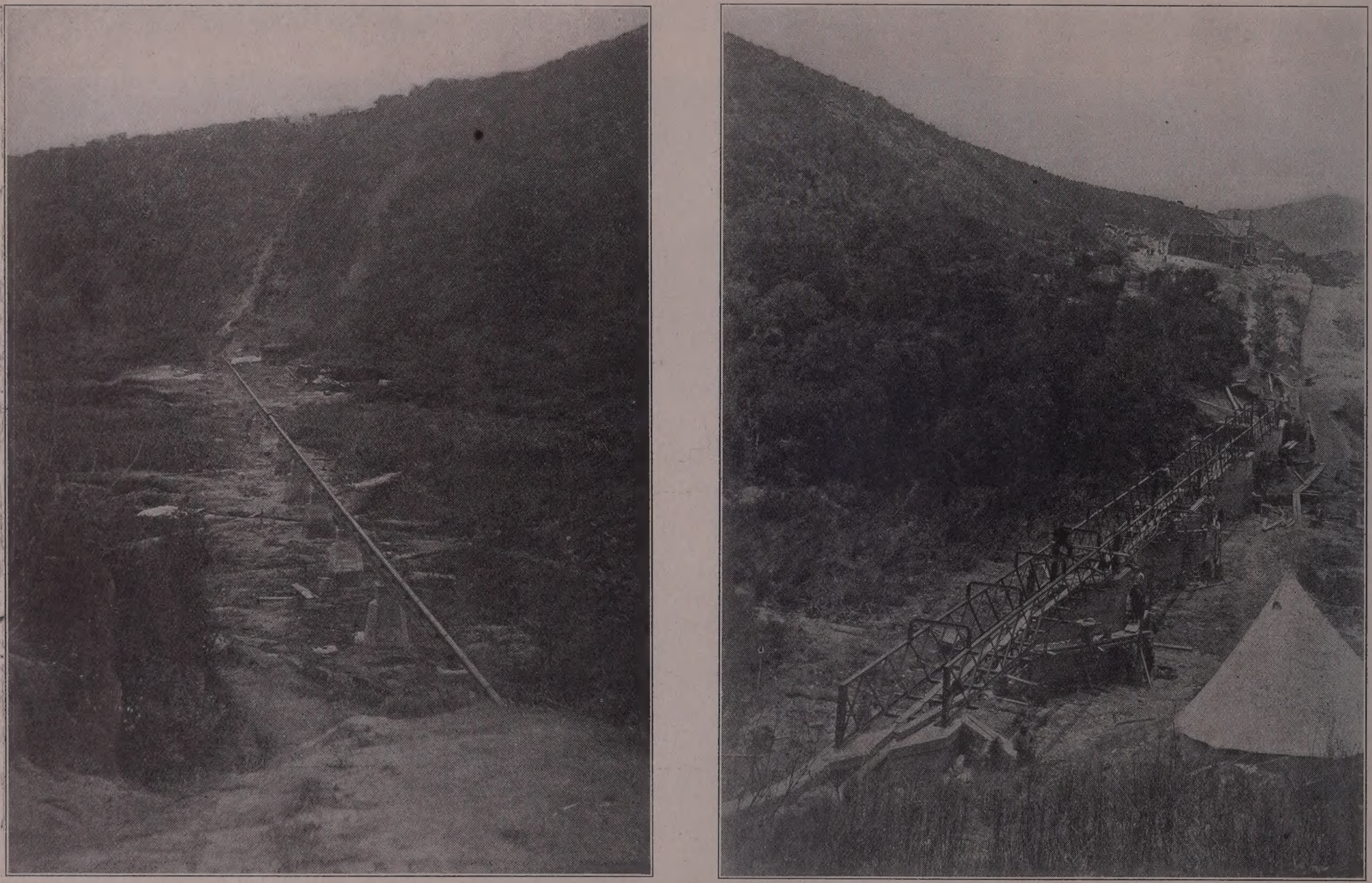
In some cases, where the contract of the parties is clear and the sum named reasonably may represent the actual loss, this amount may stand as the actual damages liquidated and agreed upon in advance and so be enforced.

The leading case on this subject was decided in England 70 years ago. An agreement between an actor and a theatre manager declared that for any breach of the agreement or any part thereof or any stipulation therein contained, the defaulting party should pay to the other the sum of a thousand pounds, which was declared to be liquidated and ascertained damages and not a penalty or penal sum or in the nature thereof. It would seem hard to use language more explicit, but the court enforced the contract only to the extent to which the manager showed himself damaged, saying that the sum named was plainly intended as a penalty, which the law would not enforce, and not bona fide as a measure of the actual damage.

The Supreme Court of the United States has followed the same rule in many cases. Thus a bond was given for the payment of $10,000 "as liquidated damages" with the condition that it should be void on the happening of a certain event within a year. The parties thus plainly declared that if the event did not happen within the year the bond should be absolute. The event did not happen until shortly after the close of the year. There was no loss to the grantee of the bond by reason of the brief delay. The Supreme Court held that the bond created a penalty; that this penalty could not be enforced in the absence of actual damage and that the use of the words "liquidated damages" did not change the character of the contract.

This same principle has been declared in many cases in the Court of Claims. A contract for transporting military supplies by steamboat on the upper Missouri River in 1877 provided that for failure to deliver any goods, twice their cost should be charged against the contractor. The Court of Claims declared this a penalty and allowed only the actual damage, the cost of the supplies, not doubled. They said: "In determining whether an amount named in a contract is to be taken as penalty or liquidated damages, courts are influenced largely by the reasonableness of the transaction, and are not restrained by the form of the agreement nor by the terms used by the parties, nor even by their manifest intent. Where the contract has expressly designated the amount named as liquidated damages, courts have held that it was a penalty; and, conversely, where the contract has called it a penalty it has been held to be liquidated damages; and again, where the parties have manifestly supposed and intended that an exorbitant and unconscionable amount should be forfeited, the courts have carried out the intent only so far as it was right and reasonable."

This principle has been followed in many other cases where the court has allowed the recovery of sums exacted as penalties. Under a contract for work on the Mississippi River levees, a forfeiture was declared by the contract of all retained percentages and the question arose whether this was a penalty requiring the United States to show its actual damages or whether this was an absolute forfeiture of the amount named as liquidated damages. The court thus stated the question: "In construing this provision of the agreements the court is led to consider whether the reserve is, by the terms of the agreements, a forfeiture



A 420-Foot Pipe Bridge and Four 60-Foot Pipe and Footway Spans on Aqueduct of Port Elizabeth Water-Works.

or penalty, or whether by necessary construction it is liquidated damages, or, in other words, compensation for what the parties agreed was to be regarded as the consequence incident to a failure on the part of the claimant to perform the work according to the requirement of his obligation." It was held that this was a penalty and not liquidated damages and that the contractor was subject only to the damages incident to his failure to perform the contract.

This decision was followed in a claim arising under a contract for improving the Harlem River. A forfeiture of the entire retained percentage was declared if the contractors failed to complete the work. The Court of Claims held that this was a penalty and not liquidated damages and that the government had to show the amount of actual damage.

A contract for erecting a building at the Zoological Park at Washington under the Smithsonian Institution provided for the deduction of $25 a day for delay in completing it. The court held that this was not liquidated damages, but a penalty. The contractor sued for ten days' penalty thus deducted and in the absence of any proof that the government suffered actual damages judgment was rendered for the contractor for this amount.

A contract for the Chandeleur Light Tower in Louisiana provided a penalty of $25 a day for delay. The government withheld $3,250, but the Court of Claims, upon very careful consideration, declared that the deduction was to be regarded as a penalty and not as liquidated damages and that as no loss was shown to the United States from the failure to complete in time, the contractors were entitled to recover this sum.

Under a contract for building the foundation of a light station in Sandusky Bay, there was a forfeiture declared of $20 for every day's delay and a deduction made of $1,280. The Court of Claims charged against the contractor the actual damage and rendered judgment for the balance exacted.

In a very recent case for the delivery of gun carriages, the government deducted $21,000, as penalty of delay, from a contract amounting to $54,000. The Court of Claims rendered judgment for this entire amount, since the United States failed to show any injury or damage whatever by the delay.

The Court of Claims has also recently rendered judgment for time penalties imposed in the construction of a snagboat under the very contract quoted in opening this chapter.

In a recent contract for clothing in the Indian Service the government deducted time penalties and also deducted twice the difference in value ascertained by an inspector between the sample and the goods furnished. The contractor secured judgment for the time penalties so deducted and for the duplicate penalty imposed for the deficiency in quality.

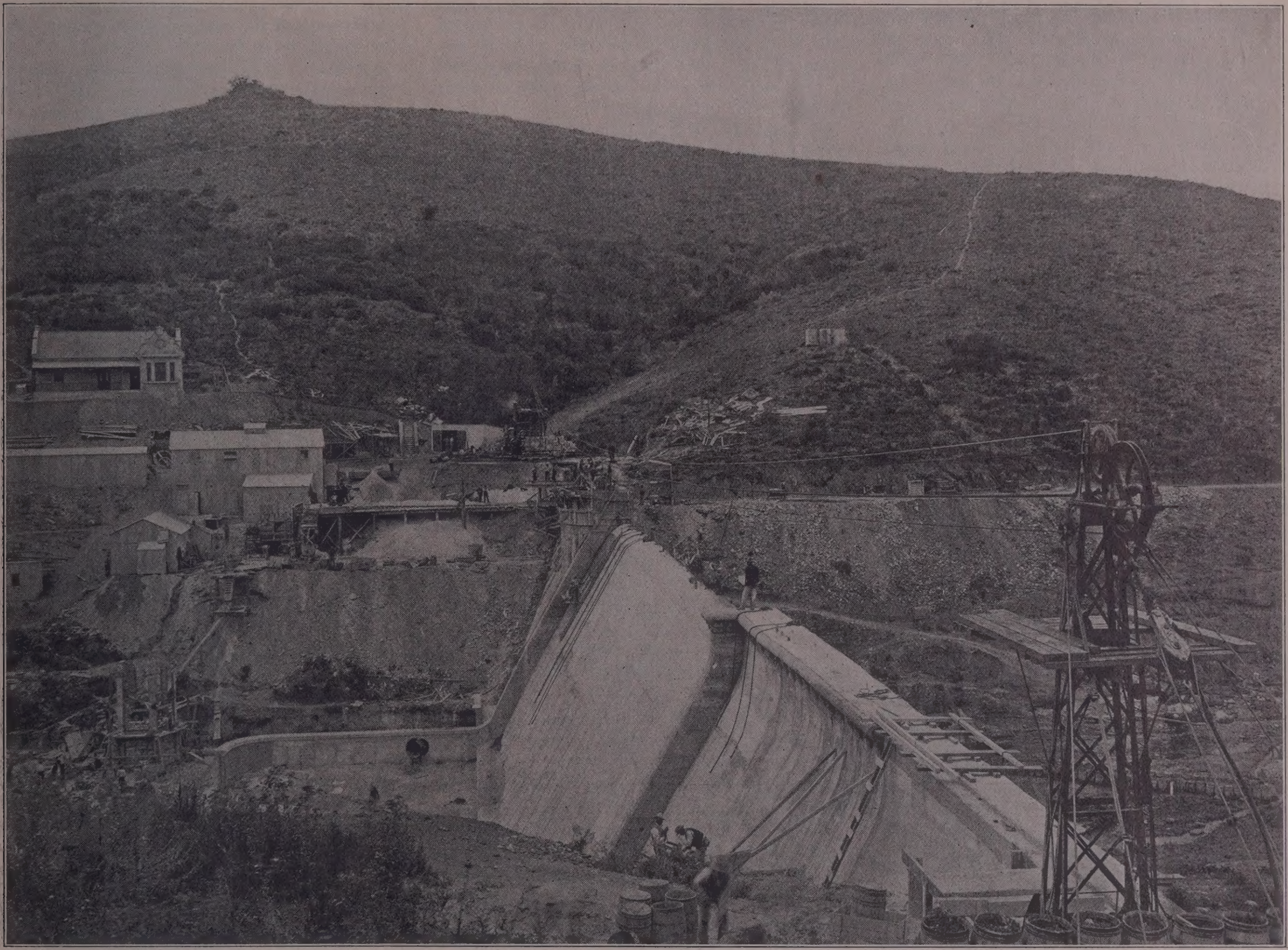
Deductions Enforced.—Notwithstanding the liberality of the rule as announced there are cases where the amount stated in the contract is regarded as reasonable liquidated damages, fixed by the parties, and is enforced.

In a contract for iron work for the Government Printing Office in Washington a forfeiture of $100 a day was declared in the contract as "liquidated damages and not by way of penalty" and the contract contained the following specific provision: "That the amount of liquidated damages is determined by actual current expenditures for rent, which are made necessary by the lack of the new building and which will cease upon its completion. But no liquidated damages in excess of $20,000 will be deducted."

The Court of Claims declared the following as its view of the law upon this subject: "While courts are disposed to construe contracts of the kind in controversy as open to the question of real or actual damages, they do not hesitate to enforce the agreement when from the terms of the contract the subject matter of the litigation it is shown that the parties have agreed to the amount as a settlement of the real or actual damage." Although they said "there is great difficulty in extracting from the cases any settled rule on which it may be decided," they concluded that in this case "the parties have themselves settled the question of damages" and enforced the agreement, saying that the enforcement of the rule in this case would not result in "unconscionable disadvantage" to the contractor.

A contract for building a bridge at Rock Island gave rise to a claim by the contractor for additional compensation for extra work. The bridge was not completed in contract time and a time penalty was claimed by the United States. The War Department refused to waive the time penalty until the contractor signed a release of his claim for extras. He did so, accompanying it by a protest, but the court held that the waiver of the time penalty was a sufficient consideration and upheld the compromise.

In one branch of the War Department a form of contract has been drawn to meet the rule de-



The Sand River Dam, Caretaker's House, Blondin, Concrete Mixer, Cement Shed and Shop.

clared by the courts. The contract first says that "time is of the essence of the contract" and then provides a certain price for the completion of the work on or before a day fixed and a lower price for its completion later. Such a contract has not come before the courts, but there seems to be little doubt that its provisions would be sustained as written.

Penalties Strictly Construed.—The general rule of law is that all penalties and forfeitures must be construed strictly. A number of cases in the Court of Claims illustrate the care of the courts in insisting that these shall not be exacted unless wholly within the terms of the contract.

A contract was made for repair of a lightship in Connecticut. The contractors sued for extra work required of them and the government responded by a counter claim for damages caused by the contractors' failure to complete their work by the date agreed. The Court of Claims found that the delay in finishing the work resulted from the time employed in doing the extra work, and that the acts both of the contractors and of the government officers contributed to the delay. Under these circumstances they refused to allow any damages against the contractors for the delay, because the government itself contributed to it.

When a contract was made for the delivery of oats, containing a provision for a forfeiture to be declared jointly by two officers, if the oats were not delivered on time, it was held that this forfeiture could not be declared by only one of the two officers named and that the dependent judgment of both was necessary to authorize the forfeiture.

A contract for work on the Philadelphia Postoffice permitted a forfeiture of the contract upon certain conditions, of which notice in writing had to be served upon the contractors. The forfeiture was declared, but the contractors were not notified in writing. The Court of Claims said of this: "The power of forfeiture must be construed strictly, and if any antecedent duty is omitted, the exercise of the power becomes unlawful, as against the rights of the other party. The agreement having provided a specific mode in which the contract was to be annulled, that mode must be strictly pursued in order to charge the claimant with the consequence of delinquency."

A contract for work on the Mississippi River gave to the engineer in charge power to declare a forfeiture in his discretion. The forfeiture was declared by the assistant engineer in the absence of the engineer in charge. The court declared that this was not a compliance with the provision of the contract and that the act was void.

A contract for harbor improvements at Philadelphia was declared forfeited and the retained percentages were held by the government. Upon reletting the work at a higher price, the government claimed a right to retain these. It was shown that the work embraced in the second contract was not the same as in the first contract. The court declared that the retained percentages could not be held forfeited under these conditions.

What Damages Recoverable.—Since actual damages only can be recovered under a penalty, the courts have necessarily been called upon to decide whether such damages really occurred and what constituted them.

A contractor at Eagle Harbor, Mich., failed to complete his work. It was taken from him and re-let for a less sum than under his contract. The government withheld the retained percentages and the contractor sued for them. The Supreme Court treated the withholding of the retained percentages as a forfeiture and said: "Unless, therefore, the government has sustained some loss, some pecuniary or legal damage by his failure, the money which he has fairly earned should be paid to him when the work which he agreed to do has been completed, though by others."

Since this work actually cost the government less than it would have cost had the claimant completed it under his contract, he was allowed to recover his retained percentages. The principle is thus established that unless actual loss is shown, the government can withhold nothing.

In the case relating to dredging at Philadelphia, just cited, the Court of Claims allowed the government to charge the contractor with the time of an inspector during the period of the extension of the contract, as an actual expense caused by the contractor's delay. Under the contract for the Sandusky Bay lighthouse, the cost of employment of the inspector during the extended period of the contract was likewise charged to the contractor.

This is the only item of actual expense which any of the decided cases have charged against the contractor in fixing penalties. An effort is sometimes made to include in such accounts vague and general allegations of loss to the United States by delays, but the courts have insisted upon strict proof and have refused to allow any expenses unless the evidence clearly shows them to be directly chargeable to the delay or other wrongdoing of the contractor.

Summary of Decisions.—This review of the decided cases shows that the courts have laid down the following principles:

(1) That where a contract declares a penalty, the courts will not allow the entire sum declared as the penalty to be withheld by the United States but will permit the government to retain only the amount of its actual losses by reason of the contractor's delay or other fault.

(2) That even if the sum to be forfeited is declared to be liquidated damages the courts will apply the same rule, unless the sum named is reasonable as an agreed amount of actual damages and the parties clearly intend it to be so regarded.

(3) That the claim of such a penalty or forfeiture by the United States is a sufficient basis for a compromise of a claim for pay for extra work by the contractor.

(4) That if the government contributes substantially to the delay or other fault charged against the contractor, the penalty cannot be enforced against him.

(5) That no allowance will be made to the government under a penalty clause unless some actual loss is shown.

(6) That the costs of inspection during the extended period of a contract are proper charges as actual expenses due to a contractor's delay.

(7) That all penalties and forfeitures will be strictly construed and will not be enforced unless the provisions of the contract authorizing them are exactly followed.

Practical Rules.—A few practical rules of importance may be laid down for the guidance of contractors.

1. Before signing a contract, all questions relating to time penalties and to forfeitures of retained percentages should be carefully examined.

2. If these are plainly declared to be penalties, then the liability of the contractor is only for the actual damages to the United States by reason of delay or other fault.

3. If these are declared to be as liquidated damages, then the liability of the contractor may be for the entire amount stated. It will not be so held by the courts if the amount stated as liquidated damages is far in excess of any reasonable measurement of actual damages.

4. When final payment is made and penalties are deducted, the contractor must protect his rights by proper protest or notice in the manner set forth in the chapter of this work on receipt in full.

(To be Concluded.)

The Construction of Pavements in Chicago.

Among the interesting papers read before the recent meeting of the Illinois Society of Engineers and Surveyors were two on the pavement work in Chicago. This is done generally under the direction of the Board of Local Improvements by special assessments. The organization of the engineering staff of the Board was described in a paper by its chief engineer, Mr. J. B. Hittle, which will be printed in a later issue, while the actual construction of the pavements was explained by Mr. J. A. Moore, assistant engineer. For this purpose, he said, the city is divided into five divisions, an engineer being assigned to each division, who takes care of all paving work in his division, of whatever nature. Nearly all preliminary work is done during the winter months, thus enabling the division engineer to devote his entire attention to construction work during that part of the year in which climatic conditions admit of paving work.

A period of time, varying from three months to three years, elapses between the time of the return of the preliminary estimate and the letting of the contract. The confirmation of assessments is frequently fought long and hard in the courts by legal talent paid by the short-sighted property owners. The term short-sighted property owners was used by Mr. Moore because in case a proposed improvement is defeated in court, as a general rule it is immediately started over again, the defect in the ordinance, estimate or assessment cured, and the battle fought all over again in the course of a few months.

During the past year competition among contractors for paving work has been unusually keen and prices have been scaled down from 15 to 25 per cent. below those which have obtained for a number of years past.

Lines and Grades.—When the contractor is ready to proceed with the work he calls upon the engineer in charge for lines and grades and plan of construction. Lines for setting curb are usually run on an offset of some even number of feet and marked by notches cut into the sidewalk. Curb foremen are required to provide themselves with steel tapes in order that offsets from the engineer's line may be correctly measured. Line and grade marks on stakes are avoided wherever possible on account of the liability of stakes being disturbed. Grade marks are usually set about 150 ft. apart, or oftener, if changes in the grade of the street make it necessary, and are placed on trees, fences, hydrants, lamp posts or telegraph poles at an elevation of 2 ft. above top of curb. Lines for return curbs for street and alley intersections are marked out on the ground. The plan of the work furnished the contractor and inspectors by the engineer is a plan of the roadway of the street, showing the location of intersecting streets and alleys, location of catch basins, summits and inlets in the gutter, crown of street, location of offset line and such other information as may be needful as the work progresses. The unusually level surface of the ground in Chicago renders it necessary to provide summits and inlets in the gutters in order to throw the storm water toward the catch basins. A minimum slope of 6 in. per hundred feet is allowable in gutters formed of granite block, brick or macadam. For concrete gutters 4 to 5 in. is allowable. The following formula Mr. Moore has found serviceable in locating the summit in gutters where they must occur at some distance from catch basins: Let $X =$ distance of summit from higher inlet, $L =$ distance between inlets, $D =$ difference in elevation of inlets, and $R =$ rate of fall in gutter in feet per hundred feet. Then $X = 0.5L - D/2R$, all quantities being in feet.

Curb and Gutter.—The first work usually done in the construction of a pavement is the setting of the curbstone, or the building of the concrete curb, or curb and gutter. Formerly 5 x 36-in. limestone curb, dressed and bush-hammered on face and top, was almost universally used, but rapid disintegration under the action of the elements has resulted in its disuse in most instances. Limestone curb is now being replaced in repaving work by Cleveland sandstone or concrete curb and gutter. Sandstone is somewhat objectionable on account of being soft while new. Where used on macadam streets it is necessary to set it with slightly open joints to prevent spalling under the crowding, to which it is subjected by the roller.

Curb and gutter is objectionable on filled streets which are to be paved with macadam; great care being necessary to prevent it from tilting up, on account of stone being forced under the edge of the flag in rolling. During the past season we constructed several miles of 6 x 30-in. concrete curbing with a fair degree of success. Expansion joints should be provided in this curb. Most of the Chicago curb and gutter is constructed of granite concrete on a foundation of cinders 6 in. in thickness. The body of the concrete consists of one part Portland cement, two parts of granite screenings and four parts of granite crushed to pass through a one-inch ring. A surface coating ⅜ in. thick is put on, consisting of two parts cement and three parts fine granite screenings. Curb and gutter is most satisfactory for brick or asphalt residence streets, Mr. Moore said, but should not be used where heavy loads come in contact with the gutter flag to any great extent.

The dimensions of the curb and gutter now being constructed by the city are curb, 7 in. in thickness, height of face varying from 3 to 4 in. at summits to 9 to 12 in. at inlets; flag, 18 in. wide and 5 in. thick. The concrete curb lately built is constructed of cement, torpedo sand and washed, crushed gravel, in the respective proportions given for curb and gutter. A good quality of concrete is obtained by the use of these materials. The theory that cement will not adhere to the polished surface of a pebble Mr. Moore regards as a fallacy.

Grading follows curbing, except in cases where fill is necessary. A considerable portion of the streets of Chicago are naturally too low to admit of adequate sewer grades without several feet of fill. Much of the city is built on ground which, before being drained, was swampy. Some time should elapse before filled streets are paved, to allow the fill to settle. The greatest source of trouble in securing stable subgrades for pavements in Chicago lies in the fresh trenches for underground work, which are commonly dug immediately preceding paving. Rolling is not sufficient to compact the earth thoroughly in a clay backfilled trench. Such trenches require time to settle.

As before stated, the plan given the contractor by the division engineer indicates the crown of the street and the depth of the gutter at summits and inlets. From this plan, the contractor sets all grade stakes. This is done by the use of T's and a two-foot rule. Ordinarily five rows of stakes are set for grading, one row in each gutter, one row on each quarter, and one row in the center of the roadway. The gutter stakes at summits and inlets are first set by measuring the depth of the gutter from the top of the curb. The center stakes at the summits and inlets are set by the use of T's, the plan showing the crown of the street or the elevation of the center of the roadway with reference to top of curb or depth of gutter. Quarter stakes at summits and inlets follow.

The contour of a cross section of the roadway takes the form of a parabola, having its axis vertical; hence, the height of the quarter stake is obtained by subtracting one-fourth of the difference in height of the center stake and gutter stake from the height of the center stake. Stakes at summits and inlets having been set, intermediate stakes are set by simply T'ing in.

The matter of setting grade stakes requires a considerable degree of intelligence in the grade foreman and careful watching on the part of engineer and inspector. The natural tendency is to get the stakes too high on streets requiring cutting and too low on streets requiring fill. When the subgrade is completed and compacted by rolling or flooding, or both, the work of paving begins.

Foundations.—Concrete foundations, usually 6 in. in thickness, are laid for all granite block, brick and asphalt pavements, except where these materials are used in resurfacing old macadam pavements, in which case enough crushed stone to bring the old pavement up to the required grade for receiving the new wearing surface is used. The construction of a concrete foundation is a most important feature of paving work. None but tested and accepted cement is used, and careful inspection is required to see that concrete is properly mixed. Most of the Chicago concrete foundations consist of one part Portland cement, three parts torpedo sand and seven parts limestone, crushed to ½ to 2 in. A considerable portion of the stone should be of small size. To secure a good concrete with these proportions of materials requires thorough mixing, especially of the cement and sand before water is applied. A fairly dry mix gives the best results, in Mr. Moore's opinion, but to secure it the inspector must be constantly on the alert, as wet concrete is mixed with less exertion on the part of the laborers. Practically all the concrete for foundations is mixed by hand. Machine mixers have been tried repeatedly by different contractors, but all, thus far, have been discarded, not because they cannot be made to do good work, but because of the increased cost of doing the work with them under the existing conditions.

Gravel, partly crushed cobble, has been substituted, in some instances, for crushed limestone, and limestone screenings for torpedo sand, with satisfactory results.

Careful attention is given the subgrade while laying concrete. Stakes are driven to the height of the top of the concrete every time the boards are moved, and the subgrade trimmed up to give the required depth.

Granite Block.—Of late some very excellent granite block pavements have been laid in Chicago. A special dressed block, furnished by quarries in Wisconsin and Minnesota, has been secured. These blocks are 5 in. in depth, 8 to 12 in. in length and 4 to 6 in. in thickness, cut to joints not averaging more than ¼ in. in width. These blocks are laid on a concrete base with a 2-in. sand cushion. Blocks of uniform thickness are selected by the paver for each course. After laying the blocks, fine gravel is swept into the joints, the blocks then rammed and the joints tarred. Asphaltic cement has been tried on both brick and granite pavements and abandoned as not giving as good results as ordinary coal tar. Some of the recently laid granite block pavements compare very favorably in uniformity of surface with well-laid brick pavements in Mr. Moore's opinion. Such pavements, while expensive, give good satisfaction and withstand the traffic where all others fail.

Samples of sandstone block pavements have been laid in downtown streets, but have failed in two or three years.

Brick.—Brick pavements, laid extensively five years ago, are now, as a rule, only used for alleys and outlying districts. Brick is laid on a concrete foundation with a 2-in. sand cushion. To secure a good pavement, it is necessary to have good brick. The great fault with paving brick seems to be unevenness in burning. A few soft brick soon ruin a pavement and are frequently hard to detect while laying. It is a good plan to moisten the sand cushion and let the brick stand over night before tarring or grouting. The soft brick will absorb moisture and remain moist sometime after the surface of hard brick is perfectly dry. It is also very essential to secure an even surface. A rough surface, with one brick projecting slightly above its neighbors, results in the jolting of vehicles passing over it, and the resulting impact soon destroys the pavement. To secure a uniform surface, the brick should be carefully culled; kiln marked and chipped brick should be rejected. The surface of the pavement should be thoroughly rolled or rammed. A straightedge run over the surface will show many irregularities, especially in the gutter, which otherwise might escape detection. Grout is now being used as a filler. Equal parts of Portland cement and a very fine grade of torpedo sand are used. Two coats of grout are applied; the first coat being mixed very thin and the second of about the consistency of cream. Quick work is necessary in applying grout to prevent the sand and cement from separating before the mixture is swept into the joints. The principal objection to grout filler is that it is necessary to keep the pavement barricaded for seven days after its application, which often works a hardship on those who wish to use the street.

Asphalt.—The wide diversity and adaptability for paving purposes of different asphalts render it exceedingly difficult to specify exactly what proportions of materials shall enter into the composition of the pavement. In making a study of this problem, the engineer finds it necessary to call to his aid the services of a skilled chemist. Proper grading of the sand in the surface coat, or the blending of different sizes to secure the minimum percentage of voids, has much to do with the life of the pavement. Much is usually left to the skill and judgment of the man at the plant, the city relying largely upon the 10-year guarantee to insure good work.

An experienced inspector is able to detect poor material, as a rule, when dumped upon the street, by the color, degree of heat and viscosity of the mass. The material should be clear black and should crumble apart by the action of gravity when dumped from the wagon. It should have a rich, oily appearance. Chicago has had a varied experience with asphalt pavements. Some pavements have failed in two or three years, others are comparatively good after ten or twelve years of use. Its smoothness, the ease with which it is cleaned and repaired and its good appearance offset its disadvantages of short life and slipperiness in cold weather. Rock asphalt has been tried in Chicago, but has not given good results.

Macadam.—Macadam pavements have always been popular in certain sections of the city. For residence districts, where streets are not subjected to heavy traffic, macadam is the most economic kind of pavement, in Mr. Moore's opinion. This is especially true where it is laid upon sandy soil. Mud and clay clinging to wagon wheels, when carried upon a macadam pavement frequently work great injury to it by reason of the pieces of stone adhering to the mud and being displaced or picked up. Many different kinds of macadam pavement have been constructed in Chicago. The kind most extensively used at present consists of a base of limestone 9 inches in thickness with a 3½-in. wearing surface of crushed granite. Second is the slag foundation, with a base of 8 in. of blast furnace slag on which is placed 3 in. of crushed limestone and 3½ in. of crushed granite.

In the construction of pavements having a limestone base, the base consists of two courses. The first course is stone crushed to 2½ to 4 in. spread to a depth to insure, when bonded and rolled, a thickness of 7 in. in the center and 5 in. at the sides of the roadway, and is bonded with limestone screenings. Upon this is placed a layer of stone broken to ½ to 2 in., spread to give, when bonded, a depth of 4 in. in the center and 2 in. at the sides. This course is also bonded with limestone screenings. The granite course consists of crushed granite, broken to ½ to 2 in., spread to give an ultimate thickness of 4 in. in the center and 2 in. at the sides. This course is bonded with gravel. After the last course has been bonded a layer of ½ in. of coarse granite screenings is spread over the surface of the pavement to act as an absorbent for any extra bonding material which otherwise might, for a time, make the pavement excessively muddy or dusty.

Other forms of macadam pavement consist of 9 to 12 in. of straight limestone laid in two courses. Eight to 10 in. of slag and 4 in. of limestone form a cheap but serviceable pavement for some outlying districts.

Novaculite has been tried and found fairly satisfactory where subjected to very light traffic, but absolutely worthless under heavy traffic. The brittle, laminated nature of this stone causes it to grind up very easily.

Gravel and crushed cobble pavements have also been laid with rather unsatisfactory results, as a rule.

The production of great quantities of slag by the blast furnaces of the Illinois Steel Co., forms the source of an inexhaustible supply of cheap paving material, especially for streets in the vicinity of the furnaces. Some grades of slag are eminently suitable for paving purposes, other grades no better than cinders. Spongy or very brittle and finely broken slag is rejected. The better grades of slag, after having been in the pavement for some time, seem to become conglomerated and partake of much of the nature of concrete. Slag is usually bonded with cinders, sometimes with limestone screenings, foundry sand or rolling mill ashes. In the construction of macadam pavements it is desirable to have the material broken to varying sizes in order that the percentage of voids be reduced. A low percentage of voids requires the use of less bonding material, which has little value in itself in resisting the wear to which a pavement is subjected.

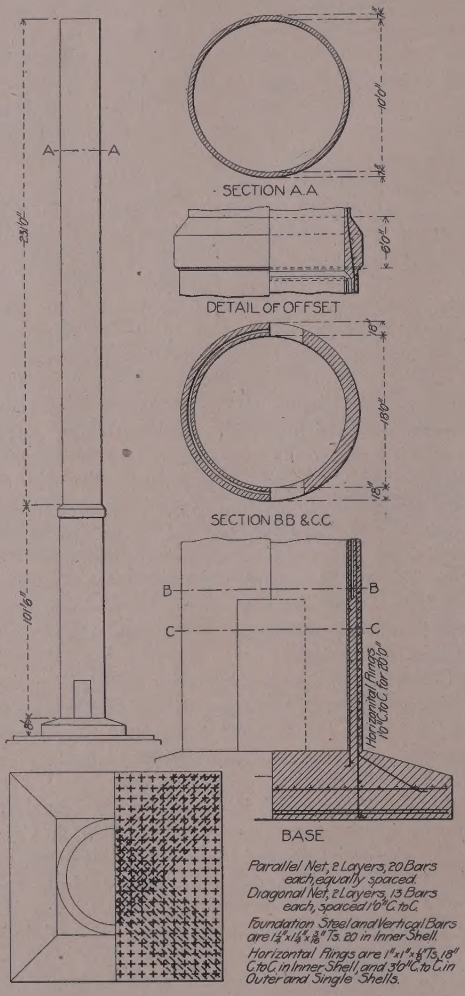
Considerable trouble has been experienced of late in securing a satisfactory grade of bonding gravel. Most of the gravel is deficient in loam and contains a surplus of torpedo sand or pebbles. The sand is especially objectionable, as giving a greater quantity of bonding material than is necessary, leaving an excess of material which rapidly forms into mud or dust and has to be cleaned up and carted off during the first year or two after the pavement has been laid.

In laying macadam pavement on clay soil, special attention should be given the subgrade, Mr. Moore said. An attempt to roll a macadam pavement on soft spongy ground only results in the mud working up through the pavement and destroying it. Such places should be dug out and filled with cinders or sand. For filled, streets which are to be paved with macadam, a course of cinders next to the pavement should be secured whenever possible.

Macadam pavements, when laid, should be taken care of. A few loads of stone judiciously placed each year will greatly lengthen its period of usefulness. It is not necessary to roll the repairs; the traffic will take care of that. One will be surprised to see how quickly a loose layer of stone placed upon a macadam pavement becomes incorporated into it.

Creosoted Block.—Creosoted wooden block pavements have lately been tried by the city with what promises to be a fair degree of success. The pavement is ideal in many respects. It is smooth, cleanly, noiseless and furnishes an excellent footing for horses. Its high cost, however, will probably keep it from being extensively used. Rectangular blocks, 4 in. in length, sawed from 4-in. Georgia pine plank, saturated with 10 lb. of creosote oil per cubic foot of timber are required by specifications. Mr. Moore believes that a more suitable wood than Gergia pine for creosoting purposes can be obtained. This wood, or a large portion of it, is so thoroughly impregnated with pitch that the extraction of the pitch under the vacuum evaporating process seems to be impossible. Blocks so impregnated cannot be thoroughly creosoted and will probably show a tendency to decay in the course of time, he thinks. As in a brick pavement, a few defective blocks will soon result in the destruction of the entire pavement.

Crown.—The matter of the crown of pavements is usually left to the judgment of the engineer in charge of the work, and should vary not only with the width of the roadway but with the kind of pavement. An asphalt street should have only sufficient crown to drain itself, owing to its slippery character in cold weather. Macadam pavements should be well crowned, as they have a tendency to keep cleaner where this is done, and rapidly wear down in the center. Brick should occupy an intermediate position between asphalt and macadam. In general a crown of 5 in. at summits and 9 in. at inlets for a 30-ft. roadway, paved with asphalt, will be found satisfactory. One inch should be added for every additional 6 ft. in width of roadway. For a 30-ft. macadam roadway, 7 in. at summits and 12 in. at inlets is recommended, with an inch added for every additional 5 ft. added to the width of the roadway. For streets having greater than 3 per cent. grade, these crowns may well be modified.


A—A
231'0"
101'6"
SECTION A.A
10'0"
7"
DETAIL OF OFFSET
6'0"
SECTION B.B & C.C.
18'0"
18"
B—B
C—C
Horizontal Rings 1'0" C. to C. for 20'0"
BASE
Parallel Net, 2 Layers, 20 Bars each, equally spaced.
Diagonal Net, 2 Layers, 13 Bars each, spaced 1'0" C. to C.
Foundation Steel and Vertical Bars are 1¼"x1¼"x3/16" Ts. 20 in Inner Shell.
Horizontal Rings are 1"x1"x⅛" Ts. 18" C. to C. in Inner Shell, and 3'0" C. to C. in Outer and Single Shells.

Reinforced Concrete Chimney, Butte.

The Concrete Chimney of the Butte Reduction Works.

The gases and fumes given off from the copper smelting furnaces of the Butte Reduction Works, at Butte, Mont., are extremely obnoxious, and when greater chimney capacity became necessary a year ago it was decided to construct a very high stack which would not only furnish the necessary draft but also discharge the gases at a great height and thus reduce in some measure their disagreeable effect in the vicinity. Accordingly a contract was awarded to the Weber Steel-Concrete Chimney Co., of Chicago, for the highest reinforced chimney built up to the present time, and one of the highest ever undertaken, being 50 ft. higher than that built by the same company at Tacoma for the American Smelting & Refining Co.

This stack stands on a base of slag 12½ ft. high, making its top 352½ ft. above the surface grade. The base was cut out of the dump from the smelter. The design was made on the basis of a velocity of the wind of 100 miles per hour. The base is 42½ ft. square, 8 ft. thick, and made of 1:3:5 concrete, reinforced as indicated in the drawings. The double shell rises 101 ft. and above it the single shell rises 231 ft., making the total height above the slag base 340 ft. The outer shell is 9 in. thick, the inner shell 5 in., the air space 4 in., and the single shell 7 in. All the shells are made of 1:4 concrete. The reinforced bars in the base and for the verticals are 1¼ x 1¼ x 3/16 in. T bars, while the horizontal rings are 1 x 1 x ⅛-in. T bars. All are of mild steel and figured for working stresses of 16,000 lb. per square inch.

The reinforcement in the base consists of two layers of 20 bars each, crossing at right angles, and two layers of 13 bars each, running diagonally. In the outer shell, and the single shell which is above it, the reinforcement consists of 460 vertical bars at the bottom decreasing gradually to 20 at the top. The inner shell has 20 vertical bars throughout its entire height. There are no wind strains on this shell, as it is entirely free from the outer shell. The horizontal reinforcing rings are spaced 3 ft. apart in the outer and single shells and 18 in. apart in the inner shell.

The stack has two smoke openings at the base, each 18 ft. high and 8 ft. wide.

Sewer Pipe Laying in a wet trench where plank supports are necessary is best done, according to Mr. Leonard Metcalf, by laying a single plank underneath the pipe and then placing the pipe in a cradle laid on that. Laying two timbers, one on each side of the pipe, and supporting the latter on bridge pieces crossing them brings the timbers nearer the sheathing of the trench than the former method. This must result, if the sheet-piling has been driven below the level of the bed of the trench, in greater settlement than when the pipe-supporting plank is in the center of the trench. In wet trenches he always aimed to keep towards the sides of the trench. He found in quicksand, where the material was very fine and running freely, that after the plank had been rammed in place, and allowed to remain for a short time, it became perfectly firm and men could walk on it without disturbing the bottom of the trench. In some difficult work at Concord, the practice was to use 3-in. plank of the width of the inside diameter of the pipe. These statements were made at a meeting of the Sanitary Section of the Boston Society of Civil Engineers, where contrary opinions were expressed by Mr. Alexander Potter. He found it difficult to maintain a drain at either side of the pipe in a quicksand ditch, as the material would slump in toward the sides and force the water to flow over the plank.

The Estimation of Costs.

So much has been written on the subject of cost keeping that it would seem difficult to add anything of much novelty. Nevertheless, in a paper recently read before the Coventry Engineering Society, Mr. A. W. Farnsworth makes several interesting suggestions concerning the employment of better men for cost-keeping. He pointed out that notwithstanding all that has been written and published, the quoted prices for engineering work to-day, based on the same drawings, specification, and information—stand as evidence that scientific methods of estimating remain in embryo. This is shown by one or two actual jobs recently let. Without mentioning names, the various tendering firms can be indicated by the letters A, B, C, D, etc. The different estimates have no connection with each other; the jobs are widely diverse, and for different parts of the country and are all for engineering appliances or tools:—

Firms.	1st estimate.	2nd estimate.	3rd estimate.
A	£ 560	£306	£5,359
B	577	309	5,550
C	588	325	5,571
D	617	345	6,020
E	709	371	6,140
F	853	375	6,177
G	926	443	6,179
H	1,022	450	6,252
J	1,205	493	6,337

Of course firm A in one estimate is not identical with firm A of another estimate. The first estimate shows a difference of nearly 115 per cent. between the lowest and highest tenderers, the second over 60 per cent., and the third nearly 20 per cent.

Progress Views Taken during the Construction of the Chimney of the Butte Reduction Works.

Most mechanical engineers will remember the London County Council engines which were let last year, and for which the lowest estimate was £84,921 and the highest was £131,857, a difference of over 55 per cent. In the face of such figures it is impossible to say that even the majority of tenders represent fair money for the articles required; we are driven to the conclusion that the making up of costs in most instances was purely arbitrary.

The accepted theory of estimating does not leave much to be found fault with. Many minds have been at work endeavoring to arrive at the essentials to correct estimating, and it is pretty generally acknowledged that the first and great essential is accurate costing of the work previously done. There are few firms of any standing who have not reams of figures at their disposal purporting to show exactly what the work they have for years been engaged upon has cost. Yet the absolute accuracy of those figures is generally doubted by the very men who have compiled them, and they are ever on the lookout for some new infallible system or some novelty in card indexing which shall give them what they are seeking.

Often past costs are turned up and efforts made to apply the figures found, but only those who try know how often this ends in wholesale rejection of the old figures and the substitution of empirical ones. Of course, when an article is standardized—such as a 12-in. lathe or similar tool—and prices are fixed, these remarks have not the same force.

There can be small doubt that ideal estimating consists in minute dissection and gradual building up of the total price from an aggregate of properly considered minor operations. There is neither no question that accurate costs of previous work are essentials to any success. The connection between costing and estimating is most intimate—in fact, 75 per cent. of the necessity for incurring expense in costing is due to the exigencies of the estimator, and with a view to future work, the other 25 per cent. being taken up with the desire of seeing that the work does not exceed its estimate, and of checking its progress and arranging that by hook or by crook it shall come within the estimated figures. The estimator is nothing without his costs, and it follows that the prime necessity of his being is that his costs shall be reliable. How to make them so is what every one interested in the question is trying to solve to-day.

The human element in costing is the dominating factor, and it cannot be got rid of unless the works grind out the same article year in and year out, and costs are kept as a fad or check merely. If every job is different from its neighbor, then considerable skill and much initiation must be shown in the handling if the results are to be worth having. Most works start a system and entrust it to the care of a good clerk, and give him as much clerical help as is thought necessary. Then, if plenty of figures result and they are neatly and carefully kept, it is considered that a perfect system is at work, and much mutual congratulation ensues. In standard articles there is often very good ground for such congratulations; but in miscellaneous and diverse work, the confidence is often utterly misplaced. In most works the workman is invited to record the time he spends; he enters it on a card or similar medium, or he confides it to a clerk who visits him daily to learn what he has been doing. Sometimes his foreman is required to check it, sometimes not. By a proper system of entering, the work can be brought up to date daily, and there are works in this country whose system has been so well developed that the head cost clerk can inform his principals as to the precise position of every job going through, the amount spent, and material bought, up to the end of the previous day, as shown by his books.

If a works is engaged upon miscellaneous work, every one acquainted by experience with the life of the shops knows that the foreman will often have to give the same man several little jobs during the day. The foreman must scheme to keep everything going as smoothly as possible, and he moves his men to suit, without regard to the cast-iron system of the cost clerk. It becomes difficult to gauge exactly how time is spent; the man puts down his time to the job which he thinks will stand it best, and if a long contract is in hand, it will get the doubtful benefit of much time which has never been spent upon it. Again, the foreman may have a very lean job on hand, and he takes care—as he can in any establishment—that it is treated tenderly, and not burdened with a good deal it might be. So that, when all the time on any job is reckoned up, it has taken so many chances of being correct, that it may be near the truth, or, as is more likely, it may be a long way off.

Then comes the apportionment of the standard costs. It is general practice to take this as a percentage on the time costs, and, though many efforts have been made to devise something better, yet the simplicity of the system, as compared with the complexity of any other way, still ensures it the first place. Staff salaries, foremen, laborers, rents, rates, taxes, depreciation, stores, coal, water, gas, lighting, and all other dead charges, are added together, and found to amount to a certain percentage of the wages bill. This percentage is added to the time costs, and the results are supposed to show the actual works costs, less the material used. The supposition is more convenient than accurate. It takes absolutely no notice of the length of time different jobs are under construction. Often it happens in a shop that a job may demand the constant presence of one or more laborers, whilst another one is hardly ever handled by them; yet the same percentage for laborers goes down on both. Again, some work may be in the shops for months, and only get one or two weeks' honest work upon it, yet the same percentage for depreciation, rent, rates, taxes, is put upon it as though it had only been about those one or two weeks.

The problem gets more difficult when day work and piecework, or premium systems, are mixed in the same shop. The same arguments apply, with redoubled force. All changing time, all wasted time, everything that can be, is laid down to the day-work job, with the consequence that the former gets a great deal more than its share and the latter a great deal less. The dead charges percentage is usually added regardless of the vastly different conditions under which the work is done, and the net result is bound to be chaos.

In taking a general survey of what is and what should be, it seems rather anomalous that the practice of separating the costing and estimating departments should be so prevalent. No business can obtain work unless the estimating department is reasonably run. The sales department may exert itself to its utmost, fortunes may be spent in advertising, but unless the estimates for work appeal to the buyers' pockets, there will soon be no business to run. Estimation hangs on good costing, and it seems to follow naturally that the two departments should be one—the man who has the draughting of the proposed costs should also handle the actual ascertained costs. This is rank heresy in some quarters; it has got to be very much the fashion nowadays to carry the old Scriptural admonition, "To let not thy right hand know what thy left hand doeth" literally into a large business, and impose pains and penalties when a man in one department learns what is being done in another. It is admittedly right to keep the junior clerk in his place and not to entrust any man with more than he knows how to carry, but perfect understanding and collaboration in a business should exist between the principal men in all departments if the utmost is to be got out of that business. If a man is not fit to be trusted with other information, although his own job is a responsible one, then it follows that he is not worthy of his own job, and the sooner he can be replaced the better.

The estimator should be the prime coster. He should not be compelled to look at totals worked up in another department by any process imaginable for his information as to how things have gone. He should see the whole make-up of these totals, and by living in them and with them he will imbue the spirit of them and be able to see in what way and for what reasons items and processes may be altered or modified. It may be objected that if he controlled the prime costing he would alter items in his books and make his costs suit his estimates, and that prime costing would then be further than ever from the truth. In some cases there might be that danger, but if he was in any way fitted for the post, one or two mistakes would give him worlds of information, and he would not fail to benefit by it. On the other hand, if complete trust cannot be put in a man occupying such a position he should be dismissed at once and never ought to have had the post. The estimating department can do more to ruin a business than all the others put together. The whole question is whether final accuracy is not worth the slight risk of collusion mentioned.

All these considerations point to the same end —estimating is largely personal. The first-class estimator must have natural gifts which fit him to exercise foresight; calculation must be his strong point. First and foremost he should be an adept in the particular business with which he is associated. This is not thought necessary in many firms. Generally, a clerk who has always worked in an office, and has shown more intelligence than his fellows, is set to work up the works costs, and his employer then puts on the margin of profit he thinks he can get. This may answer fairly well on the whole where the works are small and the employer is an engineer first and a business man afterwards, but it should not obtain in a large establishment where it is impossible for the principal personally to see and check everything. From the fact that on the correctness or otherwise of the estimate hangs the success of the firm, the man entrusted with its preparation should be the best man the firm possesses.

Sometimes the cleverest engineer is of no use as a commercial man—he cannot bring his mind to figures of pounds, shillings, and pence. But given the engineer with a thorough shop training and a capacity for financial detail—and there are many such—and we get the ideal man to fill the position of estimator to a large firm. He is not then dependent on the good-will of the managers, draughtsmen, and foremen for information—his own intimate knowledge of shop work saves him hours of worry in ferreting out particulars every day. For all ordinary work he is able to estimate without constant reference to others; for special and particular work he will take pleasure in scheming and devising in conjunction with those whose duty it will be to do the work when it is obtained. In every concern engaged in engineering there is room for a man who, from the nature of his position, must weigh the engineering and commercial features of every job thoroughly. A first-class mechanic delights in the good job turned out; the commercial engineer sees first that every job will pay, and then gives as good value as is possible. Works are not carried on to delight the souls of mechanical enthusiasts, but solely because they should be dividend-paying enterprises.

Let the best available man be given this position; promote the head draughtsman, or the works manager, or the engineer—which ever is best fitted —and then give him control of the costing and estimating, with power to direct operations if he sees anything going wrong. Make his position depend on his success; pay him largely on profits and the result would be that there would soon be fewer works existing for the apparent sole benefit of the staff.

The essentials for such a man are first-class engineering knowledge, keen business perceptions, and abundance of tact. None of them are impossibilities, but qualities to be found in many men now occupying subordinate positions. Once create such posts and there will be no lack of men to fill them. The work itself is interesting and attractive and calls for the best in every man, and engineers would willingly fit themselves for it. The bane of our trade to-day is the workman who only knows his work, and the newer generation of college-bred men who only know their books.

Give such a man some good clerks and let him devise his costing system to suit the works itself —not try to introduce some patented system only because it is reported to be working well elsewhere. As to gathering the information from the works, instead of entrusting this duty to junior clerks, who do not know a spanner from a coupling, why not take the most intelligent young mechanic in each shop or department, and let him check and verify the men's time? He should live in the shop all the time and be responsible for seeing that all time is accurately booked by the men. His own knowledge of work will prevent—if he be the right man—the wholesale misapportionment now so prevalent, and there will be at least a chance that each job gets something like its due share. It is impossible to expect a busy foreman to know each man's time on each job to an hour; he has more important duties to attend to. To be accurate, departmental expenses want careful subdivision and handling. It is not fair to put the ordinary percentage on work which requires very little labor. A great amount of discrimination and intimate knowledge of work is necessary if differentiation of any kind is to be attempted.

Improvements In Technical Instruction.

With regard to the development of educational efficiency, President Pritchett, of the Massachusetts Institute of Technology, recently stated that an institution of learning necessarily leaves much more to the individual teacher than is left in other organizations. While this gives play in a certain way to individual initiative, it also means that the changes which are made and which involve the consent of many individuals, come very slowly and only after the need for the change has been made very manifest. It has seemed to him for some years that the courses of study might be improved if they could be taken up afresh and made as nearly as possible what might be called ideal courses at the present time, and this not only with respect to the professional engineering departments, but with respect to the more fundamental subjects like mechanics, chemistry and physics.

It is somewhat singular that mathematics, the oldest of the sciences, lends itself even in our day less easily as a tool in the applied sciences than physics or chemistry. President Pritchett believed that this is due to the methods pursued in schools and universities in teaching it, a method in which the subject is separated into divisions under the heads of higher algebra, analytic geometry, differential and integral calculus and the like. When one considers that in the Institute of Technology, as in most technical schools, two years only are given to these subjects, and but a small number of hours in each year, it is not surprising that the student should fail to get a good grasp of such a tool for instance as the calculus. A wiser plan would seem to be to treat the whole time for the two years as given to a single course in mathematics; to demand of the student trignometry at entrance. Beginning, then, with the first year, the student could be introduced at once to the equation as a means of representing geometric form and could learn to derive the equations of conics as well as of higher plane curves and of other curves which have valuable properties. Having done this, he can be introduced at once to the simple machinery of differentiation and integration from which he can take up at once the analysis of all such curves, deriving the equations of tangents, normals, asymptotes by means of the calculus and determining also lengths of arcs and values of areas. In the same way he might take up most of the work which is given in higher algebra under more cumbersome and clumsy methods, with the result that at the end of the second year he ought to find himself using the calculus as a tool deftly and easily.

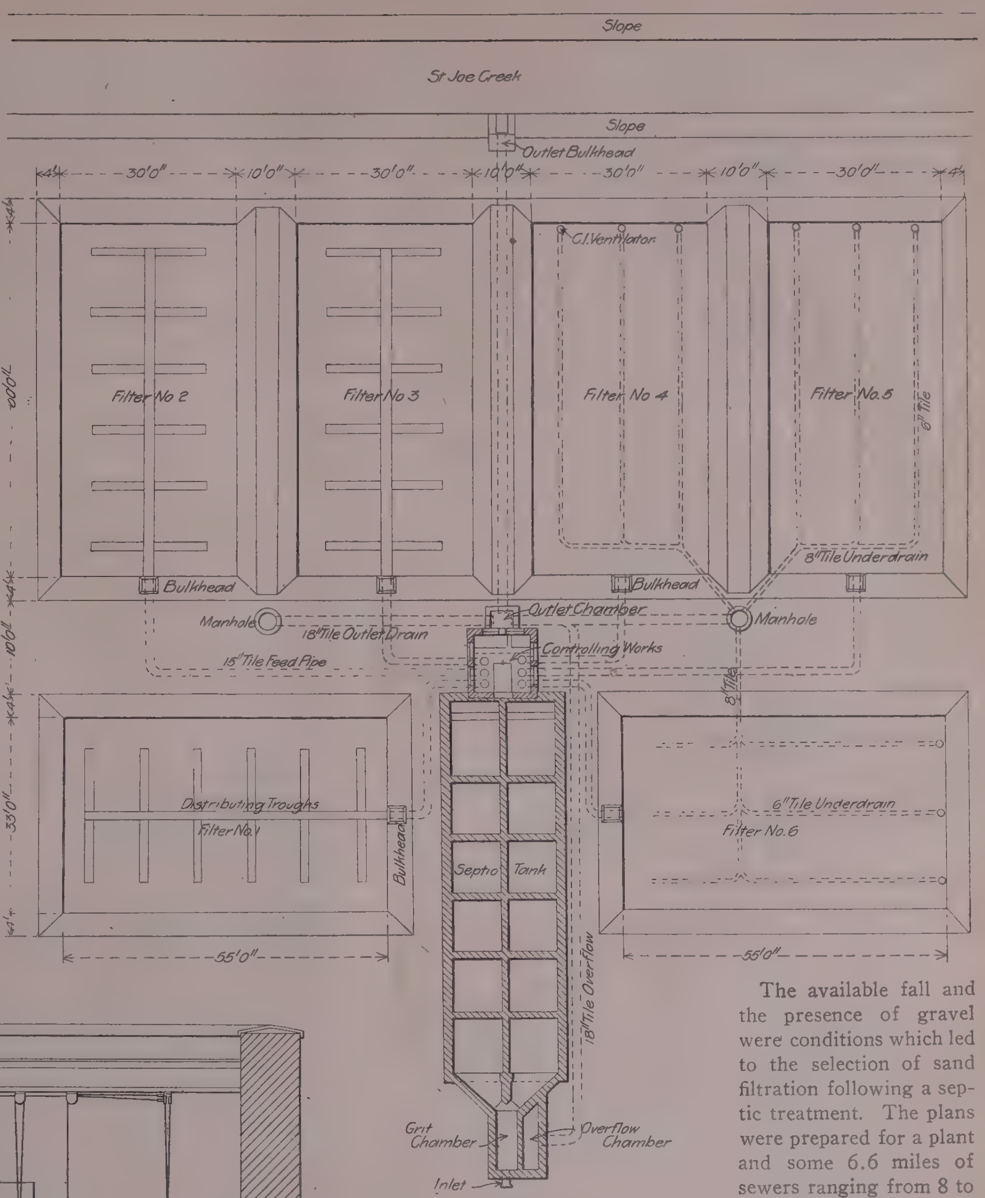
In general, without going into specific recommendations, it seemed to him clear that those who are to lead in the technical schools of America need to lend their efforts toward making as great an economy as can be effected in introducing students to the practical applications of mathematics, mechanics, physics and chemistry, to the end that these fundamental subjects may serve not only the purpose of general training, but the much larger purpose of connecting the student's thinking with the effective application of that thinking—which is, after all, the direction in which technical education ought to show its greatest efficiency.

The Sewage Disposal Plant at Downers Grove, Ill.

Paper read before the Illinois Society of Engineers and Surveyors, by W. S. Shields.

Downers Grove is a village of some 3,000 population, located on the Chicago, Burlington & Quincy Ry., 21 miles out of Chicago, in Du Page County, Ill. It has a water works system, the supply for which is obtained from two deep wells operated by an air pump. The water system was installed in 1894 and from the time of its completion until 1904 several unsuccessful attempts were made to secure a sewerage system, but owing to the then existing law requiring petitions from the owners of a majority of the frontage, nothing could be accomplished; as soon, however, as the law was amended doing away with the necessity of petitions, steps were at once taken by the Village Board for the construction of a complete system of sanitary sewers, including a sewage disposal plant.

The topography of the village is such that there was little choice of location for the disposal works, which was placed a quarter of a mile west of the village limits and some 2,000 ft. from the nearest residence; here 4.5 acres were purchased for $3,500. The land is of uneven surface and contains banks of gravel; it is well shaded by elm, hard maple and walnut trees, giving it a natural beauty not often selected for this class of works. A small creek crosses the tract and passes up through the village from west to east, and in order to get the lateral sewers from the south side of this creek across into the main sewer which parallels it on its north side, the sewer had to be laid to a flat grade. Even with 3,000 ft. of 18-in. sewer at a 0.1 per cent. grade, it was possible to get only 4 ft. of fall with which to operate the disposal works.

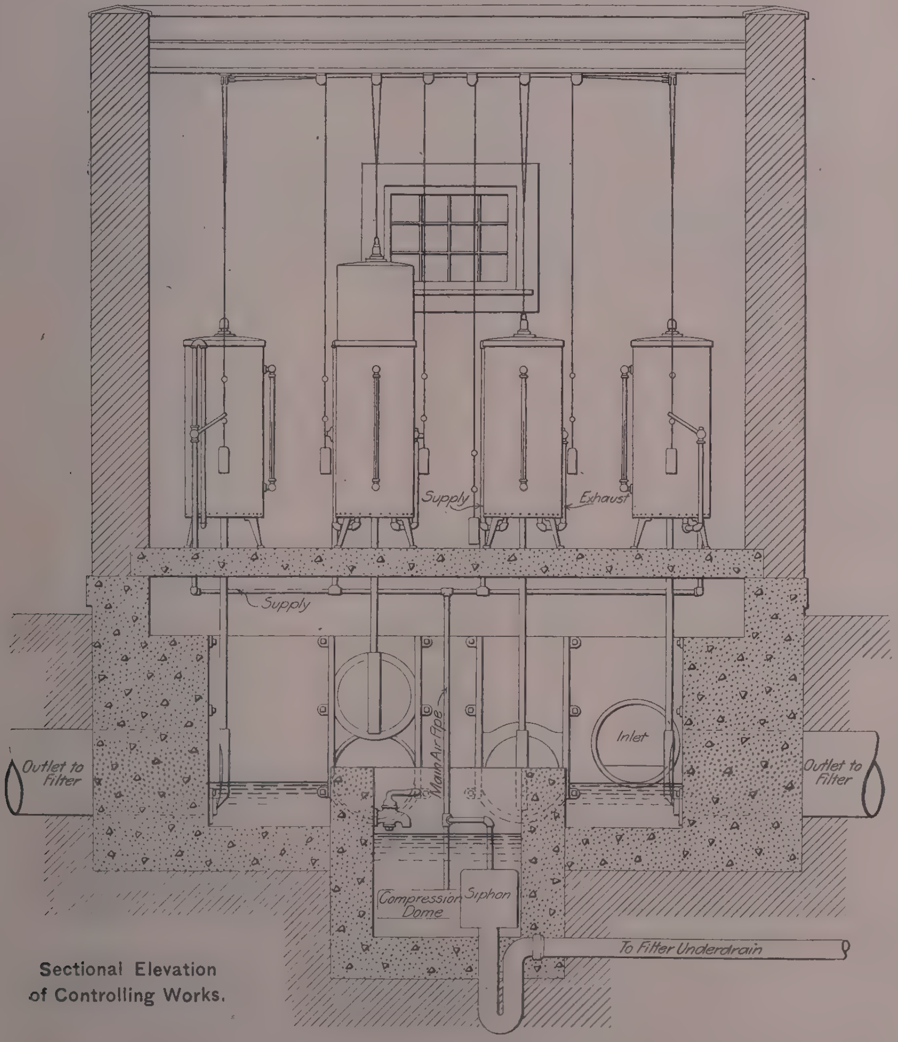


Plan of Works.

The available fall and the presence of gravel were conditions which led to the selection of sand filtration following a septic treatment. The plans were prepared for a plant and some 6.6 miles of sewers ranging from 8 to 18 in. in diameter, and an ordinance was passed which condemned the land required and a right-of-way through private property to the village street, and provided for the construction of the system of sewers, the entire cost being raised by special assessment.

The disposal plant is located upon a low spot in the valley of the creek, and consists of a concrete tank and six sand filters, each filter having 1,800 sq. ft. of filtering surface or one-quarter acre in all; the tank with its controlling chamber and filters are arranged as indicated on the general plan. The tank is a single compartment 60 ft. long by 18 ft. wide inside. It has a depth of 7 ft. at the inlet and 9 ft. at the outlet end, and a liquid content of 64,000 gal. when filled to its flow line. The covering is a flat concrete cover supported on concrete beams and five piers along the center. The roof is re-inforced with ½-in. corrugated bars and has a sidewalk surface with iron manhole frames set in the concrete. A grit and overflow chamber forms the entrance to the tank, with a by-pass around to the outlet drain.

From the septic tank the sewage flows over a weir the full width of the tank into a concrete trough, two concrete trap walls being provided to protect the surface from disturbances. From this trough the water flows into a controlling chamber, also of concrete, and from this chamber six tile pipes 15 in. in diameter, three on each side, lead to the six filters. Each pipe is provided with a 16-in. Coffin sluice valve and frame, set in the face of the concrete wall at an elevation some 6 in. below the outlet weir of the septic



Sectional Elevation of Controlling Works.

tank; these gates are brass mounted and have long stems which extend above the floor of the chamber, the gates being opened by a vertical pull. A seventh gate provided with a screw stem and wheel is so placed that when opened the water will flow through the chamber directly into the outlet. The chamber is 10 ft. square inside and surrounded with a building constructed of paving brick and covered with an ornamental tile roof; the floor is of concrete and the five windows guarded by wire screens.

In this chamber are two small compartments divided off by concrete walls, one designed for an upward filter and the other for a compression chamber. The former is connected by a 4-in. pipe with the septic tank in such a manner that the water enters at the bottom and filters upward to the surface, where it flows through a valve controlled pipe into the compression chamber. Both of these chambers are provided with drain pipes leading into an outlet chamber outside and into which the filtered effluent from all the beds enters and from which all water passes through the outlet pipe into the creek.

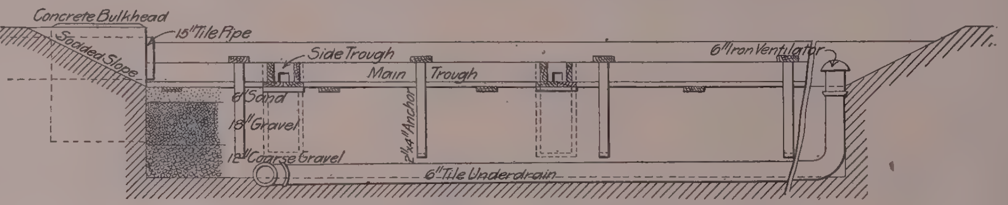
Owing to the fact that the flow from the septic tank to the filters must be controlled without any loss of head, automatic valves were used, the gate parts of which have already been mentioned. The operating portion consists of a cup vessel partly filled with liquid, and another cup inverted and placed inside of the first on the principle of a gasometer. The outer cup is provided with suitable supports and the inner or lifting dome, when not raised, rests on the bottom of the cup; two pipes enter the cup from the bottom; one terminating just below the liquid seal line admits air, and one above the liquid line provides a means for releasing the air. Extending from the bottom of the cup is a tube through which passes the stem of the gate to be lifted and a similar but larger tube is placed in the lifting dome, allowing it to rise and fall freely around the inner tube of the cup. The stem of the gate is attached to the lifting dome by means of a yoke and nut. The inlet air pipe is carried up outside the cup to a point well above the liquid seal level and then down to a connection with the compression dome, and the apparatus is ready to be operated.

The operation is brought about by air compressed by means of an air dome so placed in the small compression chamber that, as the chamber fills with water, it creates a pressure upon the air confined in the compression dome until it forces the trap to the lifting dome and raises the gate. A small siphon is placed in the compression chamber in such a way that when the valve opens, the siphon is put into operation and the chamber is emptied, allowing the compression dome to refill with air.

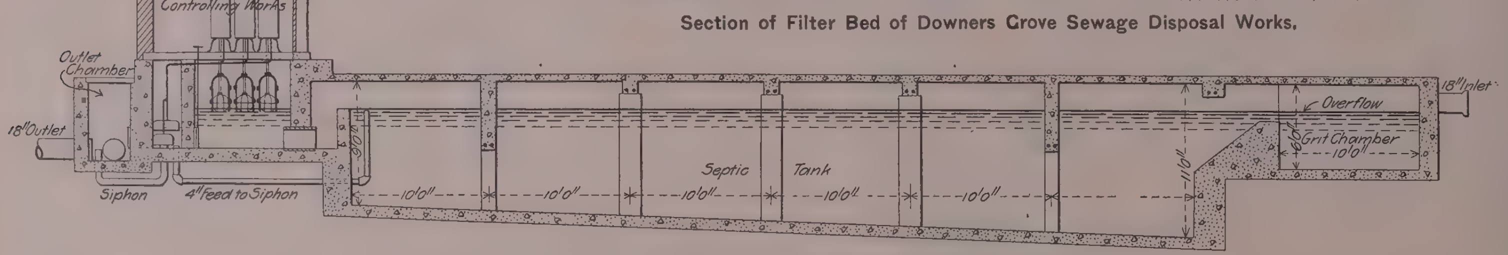
The rotation of the valves is accomplished by means of small copper chains atached to the top of the gate rod and working over pulleys in the ceiling. These chains are furnished with counterweights, and are so arranged that when a gate is raised two counter-weights drop, each opening an air cock interposed in the piping system. One weight releases the air from the last valve opened and allows the gate to close by its own weight while the other opens a similar cock in the feed pipe by which the next charge of air is directed to the valve next to be operated; these air cocks remain open until the gates drop, raising the chains and closing the cocks. The period of time in which each filter is to receive the flow is regulated by the admission of water into the compression chamber.

It is possible in many cases to obtain water from outside sources for operating the compression chamber and in this instance it is expected that the water mains will soon be extended within piping distance of the plant, when water from that source can be utilized. At present it requires approximately 100 gal. of septic effluent for each operation, but this might be reduced to 50 or 60 gal. if found necessary.

The filter beds are formed in natural excavation and embankment. The underdrains are of 6 and 8-in. sewer pipe laid with open joints, the filtering material was obtained from the gravel bank near the works, washed and screened and deposited in place by wheelbarrows. The first 12 in. is of coarse gravel with 9 in. of a finer grade on top, then 9 in. of still finer gravel, and on top of this is spread 6 in. of washed torpedo sand brought from the Fox River valley. The distribution of sewage is by means of wooden troughs, a main trough feeding branch troughs having openings on each side.



Section of Filter Bed of Downers Grove Sewage Disposal Works.



Section of Septic Tank of Downers Grove Sewage Disposal Works.

The system was completed in September and there have been about 115 houses connected to the system, yet the amount of sewage is not sufficient to test the efficiency of the plant.

Mr. F. G. Mortimer, of Glencoe, Ill., was general contractor for the entire work, which was completed and paid for in special assessment bonds, bearing 5 per cent. interest. The excavation was mostly hard clay with many granite boulders bedded in it, making it undesirable for machine digging. The entire cost of the system, including land, disposal works, sewer system and administrative costs of every kind, amounted to $54,835. The assessment was spread on a ten-year installment plan and averaged 72 cents per front foot of property abutting upon streets in which sewers were laid.

The cost of the system is divided as follows:

Land and right-of-way		$3,500.00
Disposal works, complete		8,709.64
19,120 ft. 8-in. sewer, 8.0 ft. deep, at	$0.53	15,433.60
6,355 ft. 10-in. sewer, 11.0 ft. deep, at	.76	4,829.80
3,118 ft. 12-in. sewer, 8.5 ft. deep, at	.76	2,369.68
3,324 ft. 15-in. sewer, 12.0 ft. deep, at	1.26	4,188.24
3,017 ft. 18-in. sewer, 12.5 ft. deep, at	1.56	4,706.52
206 circular brick manholes at	28.90	5,953.40
176 cu. yds. rock excavation at	3.00	528.00
Sundry extras on sewer system		276.12
Engineering and inspection		2,890.00
Legal and administration expenses		1,450.00
Total amount		$54,835.00

While the cost of the disposal works is probably a fair criterion for that class of work, the cost of the sewer system for similar excavation is probably 10 per cent. too low for profitable contracts.

In connection with this work, a partial system of storm water drains has been constructed and in this work some 2,000 ft. of 48-in. concrete sewer was constructed. The concrete was not reinforced and was put in place in the trench, which averaged 6 ft. in depth. The shell of the sewer is 8 in. thick and the invert plastered with Portland cement. The work was completed, making a very satisfactory piece of construction, at a cost of $4.80 per linear foot.

Sizes of Return Pipes in Steam Heating Apparatus.

Paper read before the American Society of Heating and Ventilating Engineers by James A. Donnelly.

It seems a very singular fact that while many papers have been written upon the sizes of steam mains and a quite elaborate treatment of the same subject is given in the works upon steam heating, return pipe sizes have been so lightly passed by. Without a single exception, as far as the writer has been able to discover, the text books have given a rule of thumb for determining the sizes of return pipes, stating that the return main must be made much larger than that necessary to carry the water, as there was an indefinite amount of air to be provided for.

Before presenting any method of proportioning return pipes it will be well to state as clearly as possible the exact functions of a return pipe, taking as an example the most difficult of return pipe problems, the dry return for an ordinary gravity return boiler system. It seems quite clear that the function of the steam main is to carry the steam to the radiating surfaces with as low a loss in pressure as practicable. This is for two reasons: First, that the radiator may be very near the temperature of the steam in the boiler and its efficiency consequently as high as possible; second, that the loss in pressure due to friction shall not be greater than that which can be restored by the available static elevation (condensation in return) of the steam main above the water line of the boiler. The return main, which, as before stated, is considered to be a dry one, must not only return the water of condensation to the boilers, but must carry back to the water line of the return where it drops to the boiler and becomes a wet return, the steam necessary to supply the radiation of the return itself, and without such loss in pressure as, added to the loss in the steam main, will be more than the before mentioned static head available between the water line in the returns and the water line in the boiler.

In other words, the dry return is essentially a steam carrying main, and the large size that is necessary in it is due solely to this fact and not to the air which may be in it, for if the air is an obstruction it should be removed by an air valve. In a paper read before this society by J. J. Blackmore, an expression was used that has been common in the market; in speaking of the return pipe he said that "the return must be large enough to equalize the pressure in the system." This statement is a great improvement upon the others referred to, even though it may not be exactly correct.

There are, generally speaking, three classes of returns for steam heating systems, and as their different functions create different conditions they must of necessity be considered separately.

PROPORTIONS FOR RETURN RISERS.

For a carrying capacity in Radiation:	286 sq. ft. In.	535 sq. ft. In.	890 sq. ft. In.	1,950 sq. ft. In.	3,600 sq. ft. In.	5,900 sq. ft. In.	12,700 sq. ft. In.	22,900 sq. ft. In.	37,000 sq. ft. In.	55,300 sq. ft. In.	78,300 sq. ft. In.
Size of steam main	2	2½	3	4	5	6	8	10	12	14	16
Size of wet return	½	¾	¾	1	1¼	1½	2	2½	3	3½	4
Size for 10 per cent. of steam	1	1¼	1¼	1½	2	2½	3½	4	5	6	7
Size for dry return	1¼	1½	1½	2	2½	3	4	5	6	7	8
Size for vacuum return	1	1¼	1¼	1½	2	2	2½	3	3½	4	5

First: The wet return, where the condensation is carried as much as possible below the water line of the boiler or return tank, or sealed by establishing an artificial water line.

General View of Downers Grove Sewage Disposal Works.

Second: The dry return in a gravity return apparatus, where the water is carried above the water line, and that part of the return which is above the water line of the returns in a wet return system.

Third: The return of what for want of a more exact classification is called a high difference in pressure system, where the pressure carried is either considerably above atmosphere and the air, water and steam from the return are usually discharged into a vented tank; or where the pressure is substantially atmosphere and the returns are carried in a pipe in which a lower pressure is mechanically maintained.

Considering first the wet return as the most simple form, there is no question but that it has only one function to perform, namely, that of returning the water of condensation. In a paper presented last year it was recommended that the steam mains should be so proportioned that the drop in pressure should not be more than one ounce in 100 ft. run of straight pipe, and, figuring the carrying capacity of wet return pipes for the same drop, their size for steam mains of the capacity given is shown in the annexed table. No allowance has been made for the extra amount of condensation due to heating up the apparatus, as this is usually spread over a sufficient time to allow the water to return without flooding the steam mains. It will be seen from this table that the diameter of the return mains is one-quarter that of the steam mains and their area one-sixteenth. This rule will give the results figured for wet return sizes if air traps and mechanical obstructions in the pipe are avoided.

Where returns are placed above the water line it is of course impossible to keep them full of water, due to the fact that they are seldom working to their full capacity and that their tendency to fill is immediaely checked by the increased velocity due to rise in static head. The space unoccupied by water is therefore filled with steam, and as it is not possible even in a horizontal dry return pipe to heat only a portion of it, the space for the transmission of the steam must be large enough to supply the steam necessary to heat the entire pipe.

The sizes given in the table as being necessary for the water only are about one-half the diameter and consequently have about one-half the superficial exposed surface of the sizes usually employed. It has been found by figuring the surface of the returns in a number of average house installations that it will amount usually to about one-tenth the surface of the radiators; assuming this to be true, or assuming that the extra size of piping called for by the heating of the return main will about double the exposed surface, the next (third) row of sizes in the table is obtained, namely, the size of pipe necessary to carry one-tenth the amount of that carried by the corresponding steam main. The combined area of the two as given in the next (fourth) line is, as will be seen, the size for dry return usually recommended.

There is, however, a possible reduction in size when the return mains are covered. If they are covered so that their radiation is cut down to from 25 per cent. to 50 per cent. that of bare pipe, the demand for steam is proportionally less and their size may be reduced accordingly.

The foregoing data seem to furnish a sufficient reason why the present sizes of returns have proven satisfactory, and yet it is not correct except for the smaller sizes of return mains, or those portions nearest the radiators. For as the return approaches the boilers the amount of steam to be supplied to it constantly decreases, and if the steam main is 6 in. and the corresponding size necessary to carry the water 1½ in., assuming the return 150 ft. long and figuring 2-in. pipe as perhaps large enough for carrying both steam and water, 150 ft. of 2-in. pipe has about 100 sq. ft. of heating surface, and this added to the capacity of the pipe necessary for water shows that a 2-in. pipe is ample for the purpose, instead of a 3-in. as generally used.

Again figuring a ten-story steam riser 3 in. in diameter, supplying 900 sq. ft. of surface, the return for water would be ¾ in.; if it fed a dry return, the amount of surface in the main return would have to be figured in determining its size; but if it was dropped into a wet return or sealed and a wet return established, the return riser would only have to be large enough to carry the water and supply itself with steam. Of course in vertical pipe, one even smaller than ¾ in. would drop the water ten stories; but assuming that it was 150 ft. high and it was made 1 in. it would contain only 150 ft. of surface and would seem to be large enough; certainly 1¼ in. would be ample.

It would therefore seem that the experiments and observations upon return pipe sizes have been made principally upon dry return systems and radiator connections, and the rule thus established applied to all systems and sizes. A sort of a paradox that the larger the return mains were made the larger they had to be, and the smaller they were the smaller they might be, would be established were it not remembered that the capacity increases faster than the area which varies proportionally as the square of the diameter and the exposed surface only directly as the diameter.

The drip from the steam to the return main is another factor that is the cause of much trouble; for as there is always a higher pressure in the steam than in the return main at any drip point, caused by the loss in pressure in the mains beyond that point, the drip pipe conveys steam as well as water and a counter flow is set up in the return main.

A strange condition sometimes exists in dry return main systems when all or nearly all of the radiators are closed; for if those left open or the drips are not large enough in effective area to keep up the pressure in the return sufficiently high, the return main will be flooded and a very puzzling situation developed. This has led to the practice of connecting all steam and return risers upon the upper floor by a direct pipe or connecting the ends of the steam and return mains where the counter flow, if any, will be up the return riser only.

Passing now to the class of systems called the high difference in pressure systems and considering their sizes of returns, the steam main has been cut down very materially in both sub-divisions of this class, at some considerable sacrifice of efficiency of radiators; many times an initial pressure has been reduced several pounds into the radiator at a loss of temperature of about 4° for every pound drop. In the systems working above atmosphere and discharging into a vented tank, the returns have very often been tried as a carrier not only of the water and air and the steam required for their own heating, but for the carrying of a large quantity of steam blown up the vent pipe. Systems of this class should undoubtedly have traps upon the radiators or in the branch returns, as from the complicated nature of the figuring involved it is practically impossible to correctly proportion the sizes of the return pipes.

The sizes of return pipes for vacuum return systems were given in a paper read before this society by R. P. Bolton. They were approximated by combining the areas of the discharge passages through the automatic valves, although these sizes were somewhat changed in a revision of the paper recently published in which it was stated that the return should be one-tenth of a square inch in area for each 100 sq. ft. of heating surface supplied by the steam main. In the Plumbers' and Fitters' Pocket Book the sizes of vacuum returns are given very much the same as in the table for those necessary for the water only. These sizes correspond to steam sizes which run as high as 160 ft. a second velocity for a 10-in. pipe, for runs up to 400 ft., and are apparently figured for a one-pound drop for that distance in straight pipe. The sizes of returns given would probably cause three or four times that drop, especially if the steam mains were carrying the radiation tabulated for them; which is about double that carried in gravity systems.

Applying the rule given by Mr. Bolton to the steam table as rated in the Hand Book, would give an 8-in. return for a 10-in. steam main instead of a 2½-in. Applying it to the smaller sizes of steam main, it gives about the same size return as for gravity systems. The sizes of return pipes for vacuum return systems can only be figured when the amount of steam drawn into them is known. As usually proportioned their superficial surface will average very much the same as gravity systems—about 10 per cent. of the radiating surface.

Of course it is very apparent that if no steam was passed by the automatic valves that a very low vacuum would be produced without jet water at the pump. Each square foot of condensing surface in them would only have to radiate 180 b. t. u. to reduce the water to the temperature of 22 in. of vacuum (153°), and the return surface at this temperature would easily have an efficiency of that amount. Where but a moderate vacuum is produced, with uncovered returns and the use of a reasonable quantity of jet water, it is certain that 20 to 25 per cent. of the steam carried out through the steam main is brought back through the return main. In that case the returns would have to be figured large enough to carry the water and that amount of steam with a reasonable drop in pressure.

With several different styles of automatic valves upon the radiators and the returns grouped and carried through controlling devices that gave a low and uniform differential throughout the installation, it has been found possible to withdraw all the air as it accumulated and to keep the steam down that was drawn into the return, so that it did not exceed 3 per cent., and the branch returns up to the differential valves have been figured to carry the water and that amount of steam, the returns from the differential valves to the pump being figured only large enough to carry the water with a reasonable allowance for air and re-evaporation.

Summing up the results of this study of pipe sizes it would seem:

That general practice often makes the steam mains too small, especially where allowance is not made for the drop in pressure in the return pipe;

That it is impossible to figure return pipe sizes for corresponding sizes of steam mains until some agreement is reached as to the uniform rating of steam mains—a general rating of steam main sizes should be adopted on the ground that efficiency of radiators should not be sacrificed where the run is short; because it is not practicable to carry steam 550 ft., without say 2 or 3 lb. drop, is no reason why small pipe should be used upon short runs in order to get this drop and inferior efficiency of radiating surface be obtained unnecessarily;

That wet return sizes and dry return sizes, where they connect to wet returns, have usually been made unnecessarily large:

That dry return systems are usually made worse rather than better by extra large sizes of return pipes, and that the main return may be made smaller, especially where it approaches the boiler.

Chicago's Fire Hazard.

The fire hazard in Chicago is apparently considered much less serious than that in New York by the National Board of Fire Underwriters. The report of its Committee of Twenty states the heaviest consumable values are in five separate districts. The most important section on account of values and hazard is the district between the river, lake and Harrison St. While it is subject to very severe vicinity fires in several places, a general fire over the whole district is improbable, owing to the chain of fire-proof buildings and the number of sprinklered risks. The packing house section is a compact group of high value, but there is little probability of a general conflagration in view of the good protection and vigilance maintained. The only bad hazard is in the lumber district.

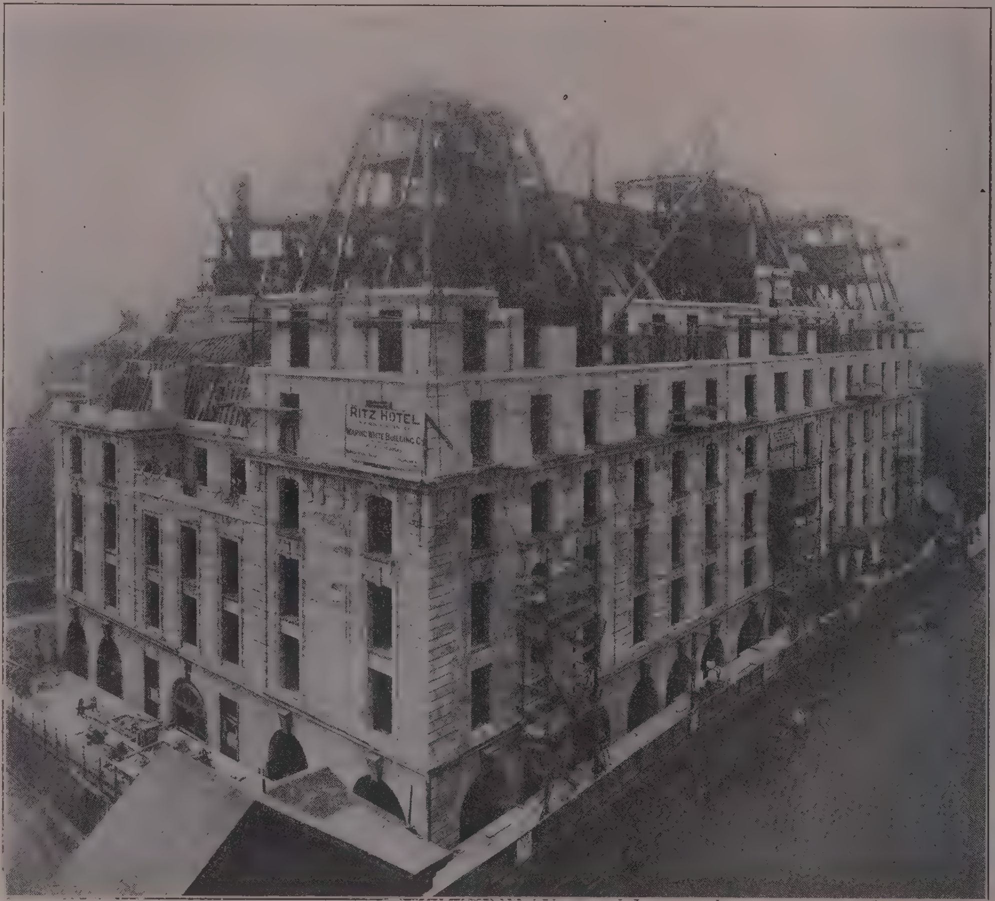
Impervious Concrete which will resist the action of sea water satisfactorily can be made, according to an article by Mr. J. W. Sandeman in "Engineering," by taking care to have the mortar in excess of the voids in the aggregate. Allowance must be made for the maximum reduction in volume of the cement and sand when made into mortar, the maximum voids in the aggregate, and unavoidable irregularities in manipulation of the concrete. When large stones are bedded in the concrete, he advises restricting the gravel to pieces of 1½ in. size and broken stone to ⅞ in. The mortar should not be leaner than one part of cement to two parts of sand.

The Construction of the Ritz Hotel, London.

The Ritz Hotel in London is a large steel frame, fireproof, six-story building, which has recently been constructed by a firm closely allied to a leading American contracting company, and in which considerable American plant has been used. Its site, about 80x150 ft., was previously occupied by two seven-story brick hotels with cast-iron H-shaped columns which supported the upper walls and the steel beam and concrete floors. The side wall footings were unsymmetrical, with extensions on the inside only. All footings were built on a solid continuous mass of concrete 3 ft. thick which covered the entire area of the site.

The buildings were demolished by a "house-breaking contractor," who first removed valuable materials in the roof and elsewhere and erected shields outside the building to prevent bricks and rubbish from falling into the streets. The walls were broken up with picks and crowbars, and the bricks put in baskets and lowered by a rope and single block, either outside the building to an area, or inside through well holes cut in the floors. At the first floor this material was, at first, carried by hand to carts in the street. After part of the building had been torn down the ground floor was used for storage of the debris from the remainder of the building, and the carts were loaded there instead of in the street. After the superstructure was thus removed an inclined wooden platform was built from the first floor to the basement and carts were driven over it to remove the remainder of the old materials.

In order to remove the 3-ft. layer of cellar floor concrete 2½-in. holes 22 in. deep and 18 in. apart were made in it by two American Consolidated Pneumatic Tool Co. drills, each of which was operated by one man and drilled about 50 holes per day. The concrete was blasted out,



Arrangement of Principal Derricks and Sidewalk Protection, Ritz Hotel.

broken when necessary by a sledge and chisels, and loaded by hand into carts. Below the concrete the general excavation was continued about 4 ft. to a depth of 22 ft. below the curb, using pick and shovel through hard, dry blue clay. The spoil was loaded by hand like the concrete into carts. Open unsheeted pits were dug about 4½ ft. deeper for the column foundations.

The party wall of the adjacent building was about 40 ft. high and was so thick and strong that it was underpinned without the use of needle beams. Pits about 6 ft. deep, 6 ft. long and 6 ft. apart in the clear were excavated under the old footing without destroying the stability of the unsupported wall above them or causing any injury to the masonry. In them new footings were built at the level of the footings for the new building, and on them brick piers were built up to engage the old wall. When they were well set the weight of the old wall was transferred to them, the spaces between the first set of pits were excavated, and the footings and brick underpinning made continuous between the underpinning piers, thus extending the old wall down to the required depth. During these operations no bracing was used except inclined shores.

Before removing the old walls below the first floor a trench, sheeted and braced in the usual way, was excavated all around the sides of the building, and in it was built a brick retaining wall 5½ ft. thick at the base and 2 ft. thick at the top, heavy enough to resist the outside pressure without bracing. This wall was waterproofed by a damp course ¾-in. thick, of asphalt applied in two layers on the inner surface of a 4-in. brick outside well built up in 18-in. courses in advance of the main wall.

The new walls have offset brick foundations and concrete footings. The column foundations are two tiers of I-beam grillages on a concrete footing 18 in. thick, carried down to a level 5½ ft. below the basement floor. The spaces between the grillage beams and for at least 4 in. all around them were filled solid with concrete, and the cast iron column pedestals were set on a ½-in. filling of grout with their planed tops 6 in. below the basement floor.

The 1:3:5 concrete was made with Anderson and J. B. White brands of Portland cement and with stone small enough to pass through a 2-in. ring. The mixed sand and stone from the Thames River was dumped on a platform, cement mixed with it and the mass turned twice by hand. Water was added from a sprinkling can, it was turned again, shoveled down about 4 ft. into the foundation trench, stamped slightly and smoothed on top.

No materials were stored at the site, all were delivered by carts about as needed, the steel was hoisted by derricks and either erected without releasing it from the slings or was temporarily deposited on the floor next below its destination. Other materials were generally taken in wheelbarrows to the three elevators located in different parts of the building. Mortar was mixed by two machines in the basement, stone was dressed on the platform built over the sidewalk around two sides of the building and just above a watertight roof protecting pedestrians from drip and falling objects.

Steel was delivered in 2-ton lots and was unloaded, hoisted and erected by one 5-ton steam guyed derrick with a 65-ft. mast and 55-ft. boom, and by two 5-ton steam stiff-leg derricks or "Scotchmen" with 75-ft. booms swinging through an arc of 270 degrees. These derricks lifted loads up to 6½ tons, the guyed derrick was like those used in New York and was operated by a Lidgerwood double-drum friction hoist. It was raised two stories at once, in four hours. The Scotchmen were raised only twice, and each operation took two days, the work being done on Saturday and Sunday so that only Saturday morning was lost for working time.

The heaviest members were handled by special methods; they consisted of three 20-ton, 39-ft. plate girders carrying exterior walls and columns in the second story. There are also eleven 11-ton cantilever girders in the basement to carry the walls adjacent to the neighboring buildings. The steelwork was assembled without much reaming; in the few cases where reaming was required it was done by a pneumatic drill. The best record for field riveting was 190 rivets driven in one day by two men and a heater, using a pneumatic hammer; three men and a heater drove about 160 rivets a day by hand. No temporary wind bracing was required for the steel framework but the columns were plumbed by guys run from the top of one column to the foot of another column and adjusted by turnbuckles.

Steam for the five derricks and the concrete crusher was made in six independent boilers, one for each. Steam at 80 to 100 lb. for the air compressor was provided by another boiler. A 200-volt electric current for lighting, and a 400-volt current for the motors in the basement which operated the elevators was procured from the Westminster Electric Supply Corporation.

The principal quantities involved in the building include about 8,000 cu. yd. of clay and 330 yd. of concrete excavated and about 2,700 tons of structural steel erected. An average force of about 300 men was employed throughout the work. The removal of the old buildings was commenced in 1903. Excavation was commenced in June, 1904. Foundations were built in July. The erection of the steelwork was commenced early in September and finished the last of December, 1904. The greatest weight of steel work erected in one week was 130 tons. The walls were commenced in December, 1904, and finished the last of May, 1905. Interior construction was commenced in May, 1905, and the building was enclosed October 1, 1905.

Besides the items already mentioned the principal plant included one 3-ton hand derrick with a 35-ft. jib, two 3-ton American boom derricks, one 2½-ton American house derrick, twelve 1-ton American house derricks, four hand crabs, two Harman cable drums for hoisting, four 15-h.-p. motors by the General Electric Co., London, one horizontal straight line air compressor with a capacity of 117 cu. ft. of free air per minute at 160 rev., two 6 ft. 4 in. x 33-in. air receivers, two pneumatic drills, six pneumatic riveting hammers.

The architects were Messrs. Mewes & Davis, of London; Mr. J. P. Bishop was the architect for the executional work; Mr. J. W. F. Bennett was the superintendent of erection; Mr. E. Wingfield Bowles, of London, was consulting engineer for heating and ventilation. The steel was designed by Mr. S. Bylander, fabricated by the Burbacher Huette, of Germany, and erected by the Waring-White Building Company, Ltd., as the general contractors for the building. The Columbian Fireproofing Co., London, was the contractor for floor construction, the National Fireproofing Co., New York, for partition tile, Yale & Towne, Ltd., New York and London, for hardware, and the Otis Elevator Co., London, for elevators.

A LARGE ELECTRICAL LABORATORY will be built at once at the Worcester Polytechnic Institute. This building has been under consideration for some time, but the recent rapid increase in the number of students has now brought about such a congestion that relief is imperative. A special feature of the new building will be a laboratory for the use of the department of electric railway engineering. The Worcester Institute is one of a few having such a course and the only one having an independent professorship in the subject.

Power Plant Economics.

Paper read before the American Institute of Electrical Engineers by Henry G. Stott.

Three years ago the steam-power plant for the generation of electricity had apparently settled down to an almost uniform arrangement of standard apparatus in which one power plant differed from another only in details of construction of engines, generators and auxiliaries. As only about twenty years had elapsed since the first central station was put in operation on a commercial basis, this uniformity of design seemed to indicate that in the near future it would only be necessary to purchase a standard set of power-plant drawings and make the necessary changes in size of units in order to have a station of the best type known to the art.

The internal combustion or gas engine had from time to time been brought forward as a candidate for the position of prime mover, with every prospect of improved economy in fuel consumption; but with the exception of a few special instances it was not looked upon with favor, as shown by the almost universal use of the steam engine.

After a long period of development a new factor in power-plant design, namely, the steam turbine, was placed on the market in commercial sizes. It is safe to say that during the last three years no other piece of apparatus has had so stimulating an effect upon the power plant. Its effect upon the entire plant has been most beneficial, for it has revived the apparently moribund superheater. This has now been so developed and improved that superheat of 200° or 300° Fahr. can be safely and economically obtained. With the development of the superheater further study of the problem of combustion has improved the efficiency of the furnace; and this most important subject is apparently susceptible of still further development.

One other important result of the steam-turbine development has been the development of condensing apparatus to such a point of efficiency that a vacuum within one inch of the simultaneous barometer reading can now be maintained without difficulty.

Another change in the power plant has been the reversion to high-speed generators, resulting in decreased cost of the generator and its foundations, as well as saving in floor space.

Last but not least the steam turbine has put the reciprocating engine and the gas engine on the defensive and has actually been unkind enough to throw out hints in regard to the application of Dr. Osler's proposed methods to the treatment of older apparatus.

The reciprocating engine and internal-combustion engine have not been slow in accepting this challenge; they have responded by showing so improved an economy (especially in the gas engine) that the situation has become most interesting to the power-plant designer. It is safe to say that the developments of the next ten years will show very marked improvement in power-plant efficiency.

In regard to this development the author wishes to direct attention to the basic fact that in power plants one should not look merely for increased efficiency in the prime mover, but should also investigate and analyze the entire plant from the coal to the bus-bars; first, in regard to efficiency; secondly, in regard to the effect of load-factor upon investment; and thirdly, the effect of the first and second upon the total cost of producing the kilowatt-hour, which is the ultimate test of the skill of the designer and operator.

Efficiency. In Table 1 will be found a complete analysis of the losses found in a year's operation of what is probably one of the most efficient plants in existence to-day and, therefore, typical of the present state of the art.

TABLE I.—ANALYSIS OF THE AVERAGE LOSSES IN THE CONVERSION OF ONE POUND OF COAL INTO ELECTRICITY.

	B.t.u.	%
1. B.t.u. per pound of coal supplied*	14,150	100
2. Loss in ashes	340	2.4
3. Loss to stack	3,212	22.7
4. Loss in boiler radiation and leakage	1,131	8.0
5. Returned by feed-water heater*	441	3.1
6. Returned by economizer*	960	6.8
7. Loss in pipe radiation	28	0.2
8. Delivered to circulator	223	1.6
9. Delivered to feed-pump	203	1.4
10. Loss in leakage and high-pressure drips	152	1.1
11. Delivered to small auxiliaries	51	0.4
12. Heating	31	0.2
13. Loss in engine friction	111	0.8
14. Electrical losses	36	0.3
15. Engine radiation losses	28	0.2
16. Rejected to condenser	8,524	60.1
17. To house auxiliaries	29	0.2
Total except items marked*	14,099	99.6
Total of items marked*	15,551	109.9
Delivered to bus-bar	1.452	10.3

Item 1. B.t.u. per Pound of Coal Supplied. The thermal value of the coal used is evidently of prime importance, as it affects the cost efficiency of the entire plant. The method of purchasing coal used in the plant from which this heat balance is derived is that of paying for B.t.u. only, with suitable restrictions on the maximum permissible amount of volatile matter, ash, and sulphur.

A small sample of coal is automatically taken from each filling of the weighing hoppers, so that the final sample represents a true average of a boat-load of coal. This final average sample is then pulverized and tested for heat value in a bomb calorimeter, after which a proximate analysis is made of another portion of the sample. This method of purchasing coal has been in use for two years, with highly satisfactory results.

Item 2. Loss in Ashes. It is doubtful whether a further saving in this item can be made, as the extra care and labor necessary to accomplish any improvement would in all probability offset the saving in coal.

Item 3. Loss to Stack. This is one of the most vulnerable points to attack, as the loss of 22.7 per cent. is very large. Recent investigations show that promising results may be obtained by the use of more scientific methods in the boiler room. In practically all cases it will be found that this loss is due almost entirely to admitting too much air to the combustion chamber, resulting in cooling of the furnace. This result is usually produced by "holes" in the fire; these "holes" may be due to several causes, but usually are due to carelessness on the part of the fireman.

Fortunately, a very valuable piece of apparatus has been placed upon the market in the shape of a CO_2 recording instrument. The results of a series of tests made with this instrument are shown in Figs. 1 and 4.

Fig. 1 shows the average condition of a furnace using small sizes of anthracite, with forced draught. The conditions are such that approximately 40 per cent. of the thermal value is being lost.

Fig. 2 shows what improvement may easily be obtained by watching the CO_2 record, and indicates a saving of about 19 per cent. over the previous case.

In the combustion of the small sizes of anthracite it is necessary to use a draught of not less than 1.5 in. of water; this breaks the crust of the fire in the thin spots, allowing the air to come through in such volumes that an enormous amount of heat is wasted in raising the temperature of the surplus air and at the same time causing inefficient combustion in the entire furnace.

Fig. 3 shows a record taken from a stoker boiler whilst the recorder was covered up to prevent the fireman from seeing the record.

Fig. 4 shows a record taken from the same stoker boiler with the fireman watching the CO_2 indications, resulting in a saving of over 12 per cent. Later records show that even better results than an average of 11.4 per cent. of CO_2 can be obtained.

Fig. 5 shows the calculated losses in fuel corresponding to various percentages of CO_2 for three different temperatures of flue gases.

From a consideration of the above tests it seems reasonable to assume that the 22.7 per cent. loss to stack can, by scientific methods in the fire room, be reduced to about 12.7 per cent. and possibly to 10 per cent.

Before the installation of the CO_2 recorder a long series of evaporative tests was made to determine the most economical draught to carry when a high-grade semi-bituminous coal was burning on the automatic stokers. The results shown in Fig. 6 were so remarkable that they were repeated under different conditions in order to confirm them. Since the installation of the CO_2 recorder, however, the explanation is apparent; as the draught giving maximum evaporation per pound of combustible corresponds to the point of maximum CO_2, illustrating the inherent difficulty of maintaining efficient conditions in the combustion chamber with high draught. This is well illustrated by Fig. 7, showing the draught, per cent. of rating, and percentage of CO_2.

Item 4. The loss in boiler radiation and leakage, amounting to 8 per cent., is largely due to the inefficient boiler setting of brick which, besides permitting radiation, admits a large amount of air by infiltration. This infiltration will increase with the draught, thus tending to exaggerate the maximum and minimum points on Fig. 6. The remedy for this radiation and infiltration loss is evidently to use new methods of boiler setting, such as an iron plate air-tight case enclosing a carbonate of magnesia lining outside the brickwork.

Mr. W. H. Patchell, of London (see paper read Dec. 7, 1905, before the Institution of Electrical Engineers), has introduced very large boilers, assembling two in one setting; each boiler has a normal evaporation of 33,000 lb. per hour and in this way has cut down to a minimum the radiating surface per square foot of heating surface. He has also introduced the iron case with magnesia lining, and with good results.

The question of boiler leakage is one in which the choice of the lesser of two evils is necessary; for in the tubular or cylindrical boiler the leakage will undoubtedly be less than in the water-tube type, owing to the smaller number of joints in the water space. But these two advantages are offset by the increased difficulty of construction, and the danger of using large boilers of the tubular type, especially with high-pressure steam.

It is now generally admitted that there can no more difference in the efficiency of different types of boilers under similar conditions than there can be in electric heaters, press agents to the contrary notwithstanding.

Item 5. Returned by Feed-Water Heater. The importance of getting the feed water to the maximum temperature obtainable is generally recognized, and would seem to indicate that all auxiliaries should be steam driven so that their exhaust may be utilized in the feed-water heater; in this way the auxiliaries may operate at about 80 per cent. thermal efficiency.

Item 6. Owing to the difficulty of pumping water at temperatures above 150 degrees Fahr., when under pressure, it becomes necessary to install economizers for the purpose of increasing the feed-water temperature to 200 or 250 degrees Fahr. As this increase of temperature is obtained from the waste gases at no expense for fuel, it only becomes necessary to consider the load-factor, as will be shown later, in order to decide whether economizers should be installed or not. In practically all cases where the load factor exceeds 25 per cent. the investment will be justified.

In deciding upon the size of economizer to be installed it is important to consider first, the influence of the economizer upon the available draught due to the obstruction it offers and also due to the reduced stack temperature; the second important consideration is to equate the interest and depreciation charges against the saving in fuel, and so determine the amount of investment justified in each particular case.

Item 7. Loss in Pipe Radiation. By the use of two-layer pipe covering, each layer being approximately 1.5 in. thick, and sections put on in such manner that all joints are broken, the radiation losses have become practically negligible.

Items 8 and 9. Heat Delivered to Circulating and Boiler-Feed Pumps. As these auxiliaries may be either electrically driven or steam driven it is interesting to note that the thermal efficiency of the electrically-driven pumps would be equal to the thermal efficiency of the plant, multiplied by both the efficiency of conversion from the alternating to direct current and by the motor efficiency. In this case, there would be a net thermal efficiency of $10.3 \times 0.93 \times 0.90 = 8.63$ per cent., whereas the thermal efficiency of the steam-driven auxiliary discharging its exhaust into a feed-water heater at atmospheric pressure would be approximately 87 per cent.

Item 10. Loss in Leakage and High-Pressure Drips. The loss in leakage should be infinitesimal, and the high-pressure drips can be returned to the boilers, so that practically all the loss under this heading is recoverable.

Items 11, 12 and 17 are probably unavoidable and of so small a magnitude as not to merit much consideration.

Item 13. Loss in Engine Friction. Recent tests of a 7,500-h.-p. reciprocating engine show a mechanical efficiency of 93.65 per cent. at full load, or an engine friction of 6.35 per cent. As this forms only 0.8 per cent. of the total thermal losses it is relatively unimportant. Attention is called to the method of lubricating all the principal bearings by what is known as the flushing system, whereby a large quantity of oil is put through all the bearings by gravity feed from elevated oil reservoirs common to all the units; after passing through the bearings the oil is returned by gravity to oil filters in the basement and then pumped up to the reservoir tanks again. About 200 gallons per hour are put through each engine, and of this quantity only about 0.5 per cent. is lost. This method of oiling undoubtedly contributes to the general result.

Item 14. As large electrical generators can now be obtained which give from 98 to 98.5 per cent. efficiency, it would seem as if the limit in design had been reached and that hereafter the problem of design is to be merely one of altering dimensons to suit varying sizes and speeds. While this is true as far as the efficiency is concerned, other problems are continually arising, such as the design of generators for an overload capacity of 100 per cent. to meet the demand for apparatus capable of taking care of great overloads economically for short periods, corresponding to peak loads of a railroad or lighting plant.

Item 15. Engine Radiation Losses. This source of loss has evidently been reduced to a negligible quantity by the use of improved methods of heat insulation.

Item 16. Rejected to Condenser, 60.1 per cent. This immediately introduces the thermodynamics of the steam engine, a subject so broad that it will be impossible to do more than touch upon some of the most important points in considering steam-engine efficiency.

The efficiency of any heat engine can be expressed by the ratio of $E = (T_1 - T_2) \div T_1$, where T_1 is the absolute temperature of the steam entering the engine and T_2 the absolute temperature of the steam leaving the engine. Thus in the engine whose steam-consumption curve is given in Fig. 8, if the initial pressure is 175 lb. gauge and the vacuum at the low-pressure exhaust nozzle is 28 in., then the maximum thermal efficiency is $837 - 560 \div 837 = 33$ per cent. This would be true for any form of engine or turbine working between the same temperature limits.

In Fig. 8, however, it is seen that the point of maximum economy shows a steam consumption of approximately 17 lb. per kilowatt-hour, which is equivalent to 20,349 B.t.u. per kilowatt-hour. One kilowatt-hour is equal to 3,412 B.t.u., so that the actual efficiency of the steam engine and generator is $= 3{,}412 \div 20{,}349 = 16.7$ per cent. As the generator efficiency at this load is approximately 98 per cent. the net engine thermodynamic efficiency is $16.7 \div 0.98 = 17$ per cent.

The difference between the theoretical efficiency and the actual efficiency is then $33 - 17 = 16$ per cent., of which 0.8 per cent. has already been accounted for in engine friction, so that the balance of 15.2 per cent. is due to cylinder condensation, incomplete expansion and radiation.

As the engine friction in a two-bearing engine with high-pressure poppet valves and low-pressure Corliss valves has by careful design been reduced to less than 0.8 per cent. gain can not be expected here, so attention must be centered on the loss due to cylinder condensation, etc., amounting to 15.2 per cent., in order to effect any improvement.

Superheated steam is the only remedy at hand and with it we can probably effect an improvement of 5 or 6 per cent. by using such a degree of superheat in the boilers that dry steam will be had at the point of cut-off in the low-pressure cylinder.

Any greater amount of superheat than this will merely result in loss to the condenser; for it should be remembered that the cylinder losses in-

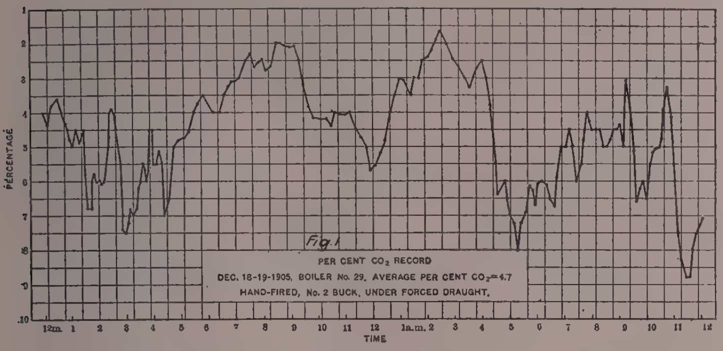


Fig. 1

PER CENT CO_2 RECORD

DEC. 18-19-1905, BOILER No. 29, AVERAGE PER CENT CO_2 = 4.7

HAND-FIRED, No. 2 BUCK, UNDER FORCED DRAUGHT.

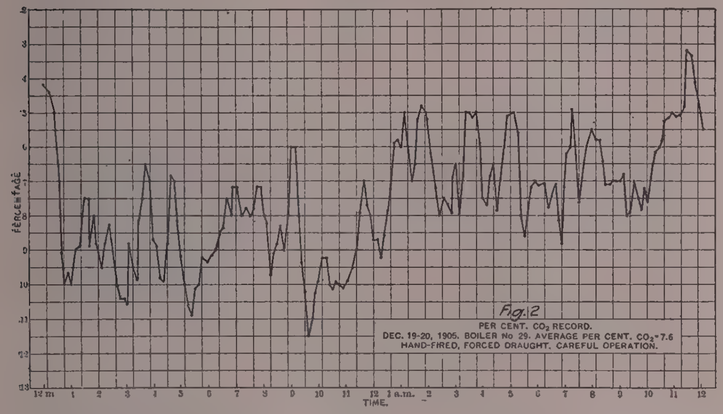


Fig. 2

PER CENT. CO_2 RECORD.

DEC. 19-20, 1905. BOILER No 29. AVERAGE PER CENT. CO_2 = 7.6

HAND-FIRED, FORCED DRAUGHT. CAREFUL OPERATION.

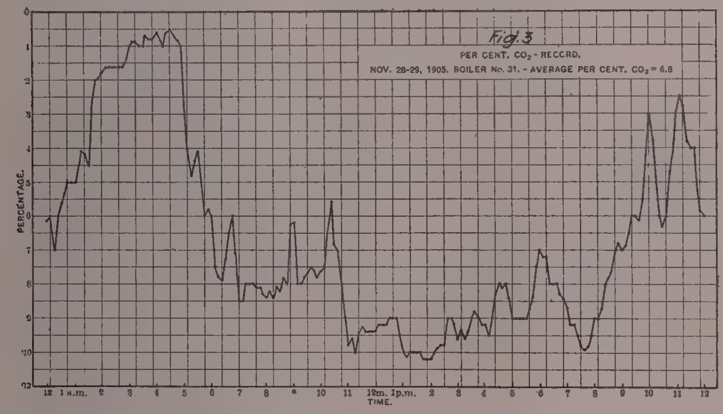


Fig. 3

PER CENT. CO_2 - RECORD.

NOV. 28-29, 1905. BOILER No. 31. - AVERAGE PER CENT. CO_2 = 6.8

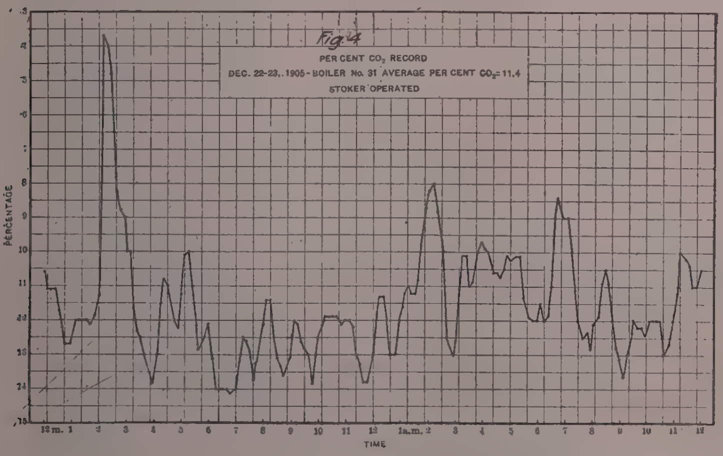


Fig. 4

PER CENT CO_2 RECORD

DEC. 22-23, 1905—BOILER No. 31 AVERAGE PER CENT CO_2 = 11.4

STOKER OPERATED

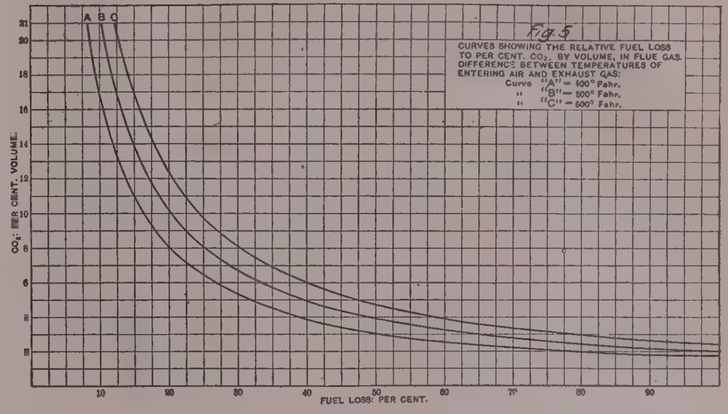


Fig. 5

CURVES SHOWING THE RELATIVE FUEL LOSS TO PER CENT. CO_2, BY VOLUME, IN FLUE GAS. DIFFERENCE BETWEEN TEMPERATURES OF ENTERING AIR AND EXHAUST GAS:

Curve "A" = 400° Fahr.

" "B" = 500° Fahr.

" "C" = 600° Fahr.

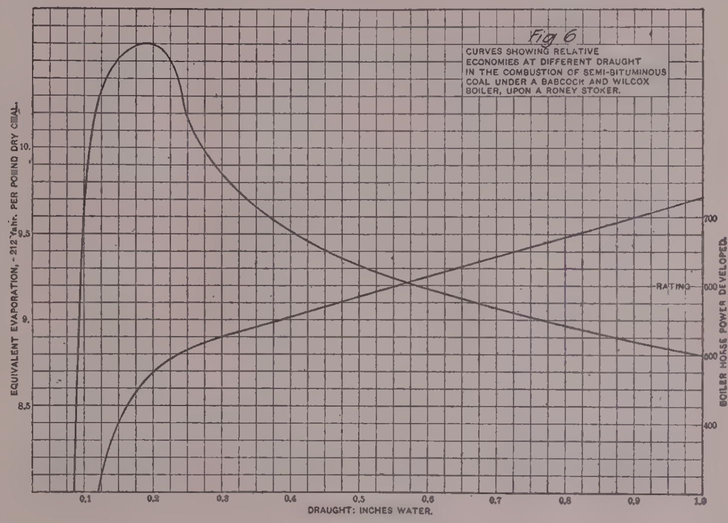


Fig. 6

CURVES SHOWING RELATIVE ECONOMIES AT DIFFERENT DRAUGHT IN THE COMBUSTION OF SEMI-BITUMINOUS COAL UNDER A BABCOCK AND WILCOX BOILER, UPON A RONEY STOKER.

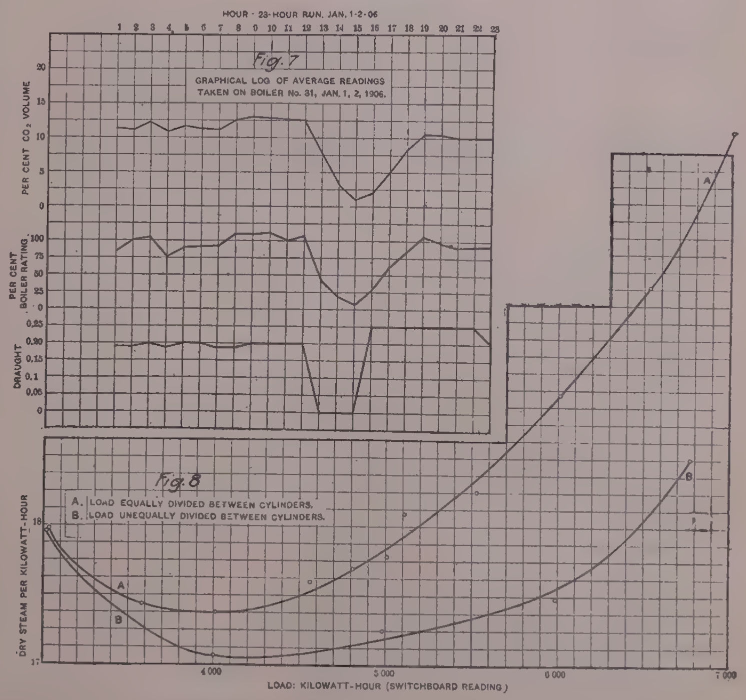


Fig. 7

GRAPHICAL LOG OF AVERAGE READINGS TAKEN ON BOILER No. 31, JAN. 1, 2, 1906.

Fig. 8

A. LOAD EQUALLY DIVIDED BETWEEN CYLINDERS.

B. LOAD UNEQUALLY DIVIDED BETWEEN CYLINDERS.

Diagrams Illustrating the Effect of Various Factors Influencing Steam Plant Economy

crease with the difference in temperature between the steam and exhaust portions of the cycle; in other words, the greater the thermal range of temperature the greater the condensation loss. This would seem to point to the use of more cylinders; but this involves additional first cost and friction as well as more space and higher maintenance charges.

Fig. 9 shows what may be gained by reducing the temperature at the end of the cycle by means of increased vacuum, but in the case in point the maximum vacuum obtainable in practice was used so that no additional economy can be expected in this way.

Summary of Heat Balance.—The present type of power plant using reciprocating engines can be improved in efficiency as follows:

Reduction of stack losses 12%
Reduction in boiler radiation and leakage... 5%
Reduction in engine losses by the use of superheat 6%

resulting in a net increase of thermal efficiency of the entire plant of 4.14 per cent., and bringing up the total thermal efficiency from 10.3 per cent. to 14.44 per cent.

The Steam Turbine.—A typical economy curve of a steam turbine is shown in Fig. 10. An inspection of this curve, which represents what is probably the best results obtained up to date, shows: first, that the best economy on dry saturated steam is practically equal to that of the reciprocating engine in Fig. 8; secondly, that 200 degrees superheat reduces the steam consumption 13.5 per cent. But calculating the total heat units in superheat from $H_1 = H + 0.48\ (t_2 - t_1)$ the B.t.u. per kilowatt-hour are 20,349 for dry saturated steam, whilst for 200 degrees superheat they are 19,008 or a net thermal saving of 6.6 per cent. The shape of the economy curve, however, is much flatter than that of the reciprocating engine, so that the all-day efficiency of the turbo unit would be considerably better than that of the reciprocating engine, with the other great advantage of costing approximately 33 per cent. less for the combined steam motor and electric generator.

Reciprocating Engine Turbine on Exhaust.—The inherent principles involved in the design of the steam turbine show that it can be expected to give an almost perfect adiabatic expansion, as there are no thermal cycles of heating and cooling at every stroke as in the reciprocating engine; there is an almost ideal thermal drop from the steam valve to the condenser. It is also evident that the expansion will be relatively more nearly adiabatic in the low-pressure stage of the turbine than in the low-pressure cylinder of the engine, so that it has been proposed that the reciprocating engine should be run high pressure where relatively it is more efficient than the steam turbine, utilizing the turbine for the low-pressure part of the cycle. In other words, use each where it is most efficient.

The following calculations show approximately what might be expected from such a combination. Assuming that the 5,000-kw. reciprocating unit would take 50 per cent. more steam when operating non-condensing than when condensing there would then be (see Fig. 8) a consumption per kilowatt-hour of 25.5 lb.

Steam expanding between the absolute pressure of 190 lb. and 14.7 lb. would give up 165.3 B.t.u. per lb., or a total of 4,215 B.t.u. per kilowatt-hour.

The total heat in the steam at 190 lb. absolute is 1.197, so that the heat units left for the turbine would be

$$(1{,}197 \times 25.5 - 4{,}215) \times 5{,}000 = 131{,}542{,}500 \text{ B.t.u.}$$

The B.t.u. per kilowatt-hour for a turbine unit operating on a dry saturated steam (see Fig. 10) were 20,349, but owing to the wetness of the steam at atmospheric pressure the efficiency of the turbine would in all probability be reduced to about 70 per cent., so that the steam consumption of the low-pressure turbine would be increased to 29,070 B.t.u. The total power available from the turbo generator would then be 4,807 kw.

We thus find that for a total of 152,617,500 B.t.u. we now get 5,000 kw. from the reciprocating unit, and 4,807 kw. from the turbo unit or a total of 9,807 kw. at a cost of 15,562 B.t.u. per kilowatt-hour.

This turbo unit would be interposed directly between the exhaust nozzle of the reciprocating engine and the condenser, and would have no valves or governing mechanism whatever. The generator would be connected directly to the other generator leads without any switching apparatus, except possibly knife switches to disconnect for testing purposes; and in operation no attention whatever would be required beyond the ordinary lubrication of bearings. Such a unit it is evident could be built at a very small cost per kilowatt.

The Internal Combustion Engine.—The gas engine has probably developed more slowly than any other piece of modern apparatus, as it is now thirty years since the Otto gas engine was introduced. It is only within the last ten years that the larger type of engine, from 500 to 2,000 h.p. in size, has appeared. The delay in bringing forward the most efficient motive power known is chiefly due to the difficulty experienced in developing an efficient and inexpensive method of making gas. As far as the production of gas from anthracite and non-caking bituminous coals is concerned this problem has apparently been solved, but it is still in a more or less unsolved condition for the richer bituminous and semi-bituminous caking coals of the Eastern States.

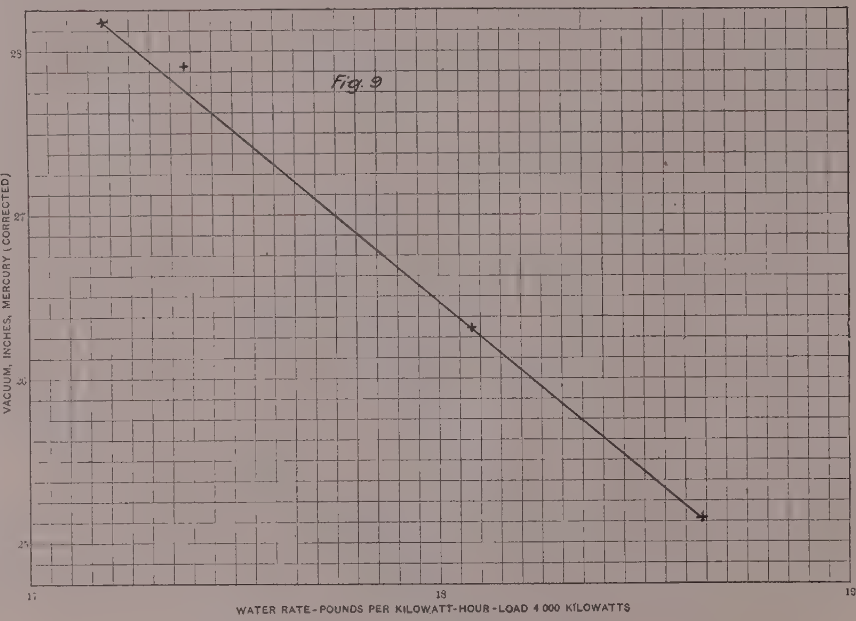


Diagram Showing Gain Resulting from Increased Vacuum.

The accompanying heat balance is believed to represent the best results obtained in Europe and the United States up to date in the formation and utilization of producer gas.

ANALYSIS OF THE AVERAGE LOSSES IN THE CONVERSION OF ONE POUND OF COAL CONTAINING 12,500 B.T.U. INTO ELECTRICITY.

	B.t.u.	%
Loss in gas producer and auxiliaries.......	2,500	20.
Loss in cooling water in jackets............	2,375	19.
Loss in exhaust gases.....................	3,750	30.
Loss in engine friction...................	813	6.5
Loss in electric generator................	62	0.5
Total losses	9,500	76.0
Converted into electrical energy.........	3,000	24.0
	12,500	100.0

The great objection to the use of the gas engine for electrical purposes has been: first, its lack of uniform angular velocity; secondly, its uncertainty in action and high cost of maintenance; and thirdly, its inability to carry heavy overloads. Recent developments have removed the first and second objections; and a period of vigorous development has resulted in placing the gas engine in the front rank of claimants for attention as a prime mover.

The total investment for a gas-producer plant, all auxiliaries, gas engines, and electric generators, has been reduced by the elimination of the gas-holding tank to a point where it is now practically on a par with a first-class steam plant using high-grade reciprocating engines.

Where natural gas or blast-furnace gas can be obtained the gas engine has outdistanced all competitors; and now that some of our large manufacturers have taken up in earnest the problem of designing producer-gas plants, it is safe to say that rapid developments will result.

The records of operation of several important installations of gas engines in power plants abroad and in this country seem to indicate that only one important objection can be raised to this prime mover, and that is that its range of economical load is practically limited to between 50 per cent. load and full load, as shown in Fig. 11. This lack of overload capacity is probably a fatal defect for the ordinary power plant, more especially for the average railroad plant operating under a violently fluctuating load, unless protected by a storage battery of comparatively large capacity.

New Type of Plant.—Over a year ago, while watching the effect of putting a large steam turbine having a sensitive governor in multiple with reciprocating engine-driven units having sluggish governors, it occurred to the author that here was the solution of the gas-engine problem; for the turbine immediately proceeded to act like an ideal storage battery; that is, a storage battery whose potential will not fall at the moment of taking up load, for all the load fluctuations of the plant were taken up by the steam turbine, and the reciprocating units went on carrying almost constant load, whilst the turbine load fluctuated between 0 and 8,000 kw. in periods of less than 10 seconds.

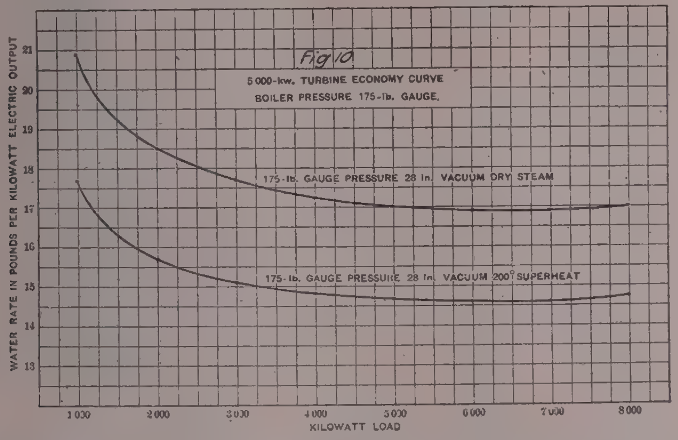
The combination of gas engines and steam turbines in a single plant offers possibilities of improved efficiency whilst at the same time removing the only valid objection to the gas engine.

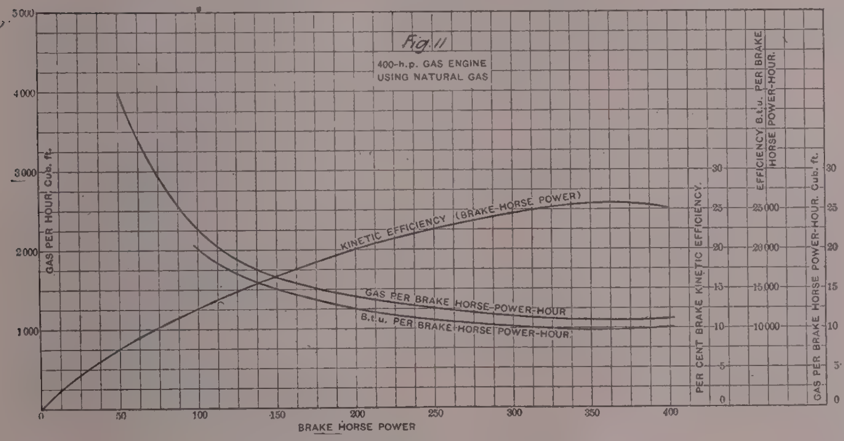
A steam-turbine unit can easily be designed to take care of 100 per cent. overload for a few seconds; and as the load flutuations in any plant will probably not average more than 25 per cent., with a maximum of 50 per cent. for a few seconds, it would seem that if a plant were designed to operate normally with 50 per cent. of its capacity in gas engines and 50 per cent. in steam turbines, any fluctuations of load likely to arise in practice could be taken care of.

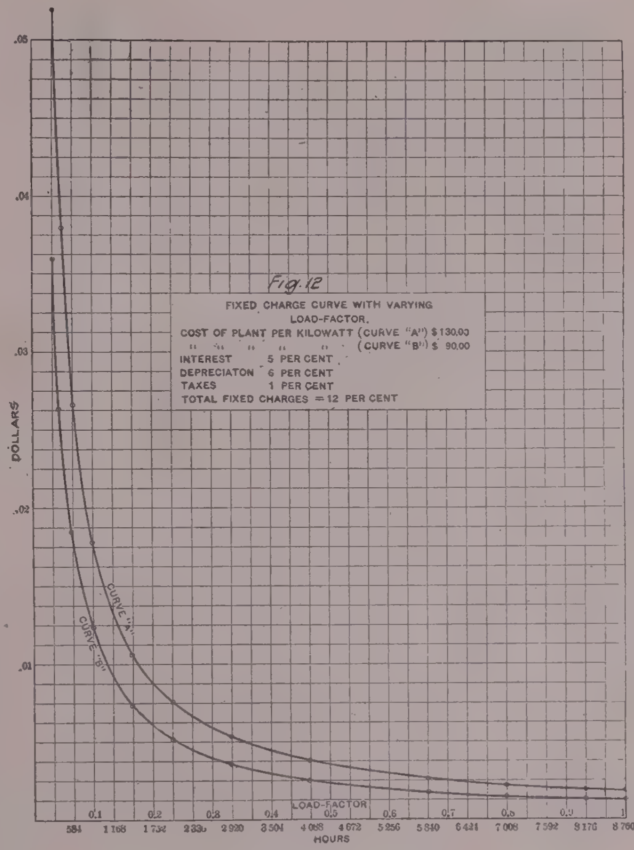
We have seen that the thermal losses in the gas-engine jacket-water amounted to approximately 19 per cent., and as the water is discharged at a temperature above 100° it can be used to advantage for boiler feed.

The jacket-water necessary for an internal combustion engine will probably be about 40 lb per kilowatt-hour, assuming that the jacket-water enters at 50° Fahr.; then the discharge temperature will be $50 + [(19 \times 12{,}500) \div (40 \times 100)] = 109.4°$ Fahr.

As the steam turbine will require only about 15 lb. per kilowatt-hour, including auxiliaries, it is evident that only 37.5 per cent. of this heat, or 7.1 per cent. of the jacket-water loss, can be utilized. The other loss in the exhaust gases of 30 per cent. can be utilized either in economizers or directly in boilers or superheaters.







Diagrams of Turbine and Gas Engine Performance and the Relation of Fixed Charges to Varying Load Factors.

Thus by utilizing the waste heat in the gas engines for the purpose of assisting to make steam for the turbines, there can be saved approximately 37 per cent. of the total heat lost in the gas engine.

In the summary of analysis of heat balance it was shown that one can reasonably expect to bring the reciprocating engine plant up to a miximum total thermal efficiency of 14.44 per cent., or possibly with steam turbines using superheat, to 15 per cent.

Referring now to Table 1 it will be noted that in Item 2 the loss in ashes was 2.4 per cent., and the loss to stack in Item 3 was 22.7 per cent.; now with the hot gases from the gas-engine exhaust it is evident that the loss in 2 will not exist, and that Item 3 will be reduced from 22.7 per cent. to about 5 per cent., as the process of combustion is completed in the gas engine. The total efficiency of conversion of this 30 per cent. of heat from the waste gases when used in the turbine plant would then be $15.0 + 2.4 + (22.7 - 5) = 35.1$ per cent.

The heat recoverable from the jacket water was shown to be 7.1 per cent. of the total heat in the coal so that there is $30 + 7.1 = 37.1$ per cent. of the original heat in the fuel returned from the gas engine, and this can be converted into electrical energy at an efficiency of 35.1 per cent.

For each kilowatt-hour delivered by the gas-engine plant, 3,918 B.t.u. will be simultaneously turned over to the steam plant, and this in turn will give 403 watt-hours to the steam plant free of cost.

The steam plant will then have only to furnish $1{,}000 - 403$, or 597 watts per kilowatt at a thermal efficiency of 15 per cent.; in other words, the economy of the steam part of the plant will be raised to $15 \div 0.597 = 25$ per cent.

The average total thermal efficiency of such a combination plant would then be $24 + 25 \div 2 = 24.5$ per cent.

TABLE 2.—DISTRIBUTION OF MAINTENANCE AND OPERATION. CHARGES PER KILOWATT-HOUR.

	Reciprocating engines.	Steam turbines.	Reciprocating engines and steam turbines.	Gas engine plant.	Gas engines and steam turbines.
Maintenance.					
Engine room mechanical..	2.57	0.51	1.54	2.57	1.54
Boiler room or producer room	4.61	4.30	3.52	1.15	1.95
Coal and ash handling apparatus	0.58	0.54	0.44	0.29	0.29
Electrical apparatus	1.12	1.12	1.12	1.12	1.12
Operation.					
Coal and ash handling labor	2.26	2.11	1.74	1.13	1.13
Removal of ashes	1.06	0.94	0.80	0.53	0.53
Dock rental	0.74	0.74	0.74	0.74	0.74
Boiler-room labor	7.15	6.68	5.46	1.79	3.03
Boiler room oil, waste, etc.	0.17	0.17	0.17	0.17	0.17
Coal	61.30	57.30	46.87	26.31	25.77
Water	7.14	0.71	5.46	3.57	2.14
Engine room mechanical labor	6.71	1.35	4.03	6.71	4.03
Lubrication	1.77	0.35	1.01	1.77	1.06
Waste, etc.	0.30	0.30	0.30	0.30	0.30
Electrical labor	2.52	2.52	2.52	2.52	2.52
Relative cost of maintenance and operation......	100.00	79.64	75.72	50.67	46.32
Relative investment in per cent.	100.00	82.50	77.00	100.00	91.20

Load-Factor and Investment.—In Fig. 12 the interest, depreciation and taxes on a plant costing $130.00 per kilowatt, which may be taken to represent a first-class steam or internal combustion plant, is shown plotted in conjunction with various load-factors.

Another curve is plotted showing the minimum investment with a plant in which the prime mover would be steam turbines and designed otherwise without regard to efficiency, leaving out economizers, feed-water heaters, etc., and thus reducing the investment to $90.00 per kilowatt. This cheap and relatively inefficient part of the plant would only be operated on peak loads of two or three hours' duration, corresponding to a load-factor of 0.1 or less found in possibly 40 per cent. of the output of our lighting plants.

In Table 2 will be found a tabulation of the relative values of the various items necessary in the maintenance and operation of a power plant. The first column covers a plant with compound condensing reciprocating engines without superheat, and is derived from a year's record of actual costs of a large plant operating with a load-factor in this case being defined as actual output divided by 24 times the maximum hour's load.

The values in the other columns have in the main been estimated from the first column, but wherever possible actual data derived from various sources, both domestic and foreign, have been used; but in all cases all values have been reduced so as to make them directly comparable with the first column, and with one another. The values in maintenance and operation of steam turbines are derived from actual costs.

Summary.—1. The present type of steam-power plant can be improved in efficiency about 25 per cent. by the use of more scientific methods in the boiler room, by the use of superheat, and by running the present types of reciprocating engines high pressure, and adding a steam turbine in the exhaust between the engine and the condenser. At the same time the output of the plant can be increased to double its present capacity at a comparatively small cost for turbines and boilers.

2. The steam-turbine plant has an inherent economy 20 per cent. better than the best type of reciprocating-engine plant, not so much due to its higher thermal efficiency as to a variety of causes shown in Table 2.

3. An internal-combustion engine plant in combination with a steam-turbine plant offers the most attractive proposition for efficiency and reliability to-day, with the possibility of producing the kilowatt-hour for less than one-half its present cost.

In conclusion the author wishes to acknowledge the kindness of the Westinghouse Machine Co., the General Electric Co., and the Allic-Chalmers Co., in furnishing data on steam turbines and gas engines, and also the work of his assistant, Mr. W. S. Finlay, on data and preparation of curves.

Data on Furnace Heating.

In answer to a series of questions prepared by a committee of the American Society of Heating and Ventilating Engineers to bring out data in regard to furnace heating problems, replies were received from Messrs. Wm. G. Snow, Boston, and J. P. Bird, Putnam, Conn. These replies and the questions themselves were substantially as follows:

1. What rule or formula would you use for obtaining the heat lost by conduction and radiation from buildings through walls, windows, roofs, etc., and the heat lost by warm air escaping from the building?

Wm. G. Snow.—Ordinary walls, either 13-in. brick or good frame construction, transmit roughly one-quarter as much heat as the same area of glass. Base the loss of heat through glass with 70° F. difference in temperature at 85 heat units per square foot per hour, to be increased 25 per cent. for north or west exposure and 15 per cent. for east. The loss of heat through a ceiling separating a room from an unheated attic space may be taken approximately as one-twentieth the loss of heat through the same area of glass with 70° inside and zero out. In other words, the equivalent glass surface of the ceiling, as above stated, is equal to the area of same divided by 20. Each cubic foot of air escaping at 70 degrees in zero weather carries practically 1¼ heat units.

J. P. Bird.—Multiply the calculated amount of the equivalent glass surface by 85, which gives the loss of heat per hour by transmission through the exposed walls, with the difference of 70° F. in temperature between the conditions inside and outside the house. To determine the loss by the warm air escaping from the building, add to this amount 1¼ heat units for every cubic foot of air lost at 70° F. through ventilation. This factor, 1¼, is based upon the fact that one heat unit will heat one cu. ft. of air through 55°, so that for every cubic foot of air lost at 70°, and which has therefore had to be heated through 70°, there will be 70/55 the heat units lost per cubic foot, or approximately 1¼ heat units.

2. The sum of these two losses is the total heat that must be supplied to the circulating air by the furnace. What quantity of air should be passed over the furnace in order to absorb this amount of heat?

Wm. G. Snow.—Let the total heat supplied to the circulating air per hour equal H. Assume that the air is heated from 0 to 140°. One heat unit will heat (in round numbers) 50 cu. ft. one degree, or will heat 1 cu. ft. 50 degrees, or 0.357 cu. ft. 140°. Hence H will heat $H \times 0.357$ cu. ft. from 0 to 140°. For example, a furnace with a 26-in. pot giving off 139,000 heat units per hour would heat about 50,000 cu. ft. per hour from 0 to 140°.

J. P. Bird.—Divide the heat lost by transmission by 1.1, when the quotient will give the volume of warm air required per hour, which amount when divided by 60 gives the volume of warm air required per minute. This figure is based on air issuing into the rooms at 130° and escaping at 70°, its drop in temperature before it passes from the building giving up the heat that the walls will transmit. How this figure is obtained may be readily seen. The figure usually taken to connect heat units with the warming of air is that one heat unit will raise one cubic foot of air through 55° or, vice versa, that in abstracting one heat unit from air one cubic foot will be cooled 55°. Now with air entering at 130 and escaping at 70 (that is, being cooled 60°), each cubic foot of air will give up more than one heat unit or 60/55 heat unit, equal to 1.1. As the calculated loss by transmission through the walls gives us the number of heat units supplied in an hour by the cooling of the air, and as one cubic foot gives up 1.1 heat units, the number of cubic feet will evidently be the quotient of the transmission loss divided by 1.1. If it is desired to use a similar formula for determining the amount of air on the basis of the total heat loss, it must be remembered that the air is raised from the outside temperature to the temperature at which the air is admitted into the rooms. For zero weather and 130° at the registers, this means that each cubic foot of air is raised through 130° and that the total amount of air required will be found by dividing the total heat loss by $130 \div 55 = 2.47$. For a temperature of minus 10° outdoors, the range of temperature through which the air must be warmed is 140°, and the dividing figure is consequently $140 \div 55 = 2.55$.

3. Suppose the outdoor temperature is zero and the temperature of the hall or other part of the house from which air may be drawn into the cold air box is 60 degrees, what proportion of the air would you draw from the outside and what from the inside in an ordinary dwelling house of 8 to 12 rooms?

Wm. G. Snow.—This would depend a great deal upon the use of the rooms at the time. For example, at night, when fresh air in sleeping rooms could be taken in through windows slightly raised, all the air could be returned from the house. In case an unusual number of occupants were present and a good many gas lights were burning, all the cold air should be taken from the outside. Between these two limits any desired proportions to meet existing conditions could be adopted.

J. P. Bird.—Never have practiced this plan, but think a system could be installed with a considerable saving of fuel. Taking an 8-room house occupied by six persons there are probably no more than three persons in the house during the 10 hours of the day, when the air could be recirculated with no ill effect. A duct should be provided from the outside of three-fourths the size of the combined area of all the hot air pipes and a duct from the inside of the full capacity of the combined hot-air pipes, this one to be connected into the cold-air duct. A wind damper should be provided, and gossamer flaps to prevent back drafts.

4. How would you calculate what would be the maximum temperature of the air passing over the furnace. Do you consider this the most advisable temperature of the air at the outlet?

Wm. G. Snow.—Take, for example, a furnace with a 24-in. grate and 3 sq. ft. of free area for the passage of air; we might safely assume that the velocity would be 275 ft. per minute, corresponding to 49,500 cu. ft. per hour. A 24-in. grate burning coal at the rate of five pounds per square foot an hour, and assuming the utilization of 8,000 heat units per pound of coal, would give 125,200 heat units per hour transmitted to the air. Since one heat unit will raise 50 cu. ft. of air 1°, 125,200 heat units would raise 49,500 cu. ft. 127°. Anywhere from 120° to 140° would be considered a fair temperature for furnace heat.

J. P. Bird.—The amount of heat that one cubic foot of air will take up per degree rise in temperature is equal to $0.2377 \times 0.0864 = 0.0205$ heat unit. This is, of course, the product of the weight of one cu. ft. of air, 0.0864, by the specific heat of air, 0.2377. Assuming that the house will require 84,000 cu. ft. of air per hour, which is apparently based on four changes per hour, a furnace having a 32-in. grate is selected, or 5.58 sq. ft. of grate surface. Taking a rate of combustion of 5 lb. of coal per square foot of the grate per hour, and assuming that 1 lb. of coal supplies 8,000 heat unit to the air, this amount of coal will give off $8{,}000 \times 5 \times 5.58 = 223{,}200$ heat units per hour. This is the total amount of heat that can be supplied by the furnace at the stated rate of combustion. To heat the hourly supply, 84,000 cu. ft. of air, $84{,}000 \times 0.0205 = 1{,}722$ heat units are necessary for every degree rise, so that the 223,200 heat units supplied from the coal will heat the given amount of air about 130° ($223{,}200 \div 1722 = 129.6$). It will be seen that in determining this temperature, the amount of air passing through the building and also the rate of combustion has been assumed for zero weather. Consider 130° the most advisable temperature of the air at the outlet, at least one not exceeding 140°.

5. What rule or formula have you for proportioning the extent of the heating surface of the furnace to the maximum quantity of heat to be given to the air by the furnace?

Wm. G. Snow.—One sq. ft. of heating surface should not be relied on to give off more than 2,500 heat units per hour. Take the case cited in No. 4. Such a furnace would have in round numbers 50 sq. ft. of heating surface and would give off 2,500 heat units per square foot per hour. It would be better, of course, to rate the furnace at not over 2,000 heat units per square foot an hour. As a rule, furnaces have from 15 to 20 sq. ft. of effective heating surface per square foot of grate. Many furnaces have a great deal more than this, but much of the surface is relatively inefficient.

J. P. Bird.—Prefer 12 sq. ft. of heating surface to one sq. ft. of grate surface, assuming 5 lb. of coal burned per sq. ft. of grate per hour. Have no formula for extent of heating surface.

6. What rule have you for diameter of fire pot, depth of fire pot, diameter of grate and for maximum rate of combustion per square foot of grate surface per hour?

Wm. G. Snow. The depth of the fire pot should be not less than 12 in., and the dome above it should be high enough to provide for carrying the pot heaping full of coal in cold weather. I find the maximum rate of combustion advisable to maintain in the coldest weather to be not greater than 5 lb. per sq. ft. per hour. With a cast iron pot this rate is likely to make red-hot surface.

J. P. Bird.—One pound of anthracite will emit 13,000 heat units, but I think 60 per cent. is as much as can be utilized; in round figures, say 8,000. Assuming 1 sq. ft. of grate will consume 5 lb. of coal per hour, the combustion will give us 40,000 heat units per square foot of the grate. Dividing the total loss of heat for the house per hour by 40,000 will give us the area of the grate required. As most of our furnaces have tapering fire pots, I find that the average area will be that of the grate.

7. What rule have you for determining area of pipe admitting cold air from outdoors? If pipe is used for inside circulation, what then?

Wm. G. Snow.—I would advise making the cold air box not less than 75 per cent. of the combined area of the hot air pipes, and I consider a larger area of cold air boxes to be better, in view of the greater ease in keeping the house at a moderate temperature in mild weather by supplying a surplus of air through the registers beyond what would be required in the winter for heating the house. If inside circulation is provided I would consider that merely supplemental to the regular cold air supply and would control it by a separate damper or have a swinging damper arranged to automatically cut down the cold air supply when the return air is being used.

8. What rule have you for area of heater pipes leading from furnace to first, second and third floors?

Wm. G. Snow.—The theory on which the size of the pipes would be based would require too much space to state fully in connection with these questions. The committee is referred to pages 37, 38, 39 of the treatise on "Furnace Heating," by Wm. G. Snow.

J. P. Bird.—Glass surface plus one-quarter the wall surface plus one-twentieth ceiling or floor area, when the attic or cellar is not heated, with 10 per cent. added for exposed places, gives the area of the equivalent glass surface. The equivalent glass surface multiplied by 85 gives the number of the heat units lost per hour. This result divided by 1.1 gives the volume of air per hour, and this result divided by 60 gives, of course, the volume of air required per minute. If the volume is divided by the velocity in feet per minute, the quotient, which will be in square feet, when reduced to square inches will give the size of the pipe required. I base the velocities at 280, 400 and 500 ft. per minute for the first, second and third floors. Take the following example: Assume a room 12 x 14 x 9 ft. in size, with 39 sq. ft. of glass surface and with two sides exposed toward the northwest. $12 \times 9 + 14 \times 9 = 234$; $234 - 39 = 195$; $195 \div 4 = 48\frac{3}{4}$ or 49; $49 + 39 = 88$ sq. ft. equivalent glass surface. Ten per cent. added for severe exposure gives 97 sq. ft. equivalent glass surface. $97 \times 85 = 8{,}245$ (heat units lost per hour); $8{,}245 \div 1.1 \div 60 = 124\frac{5}{6}$ or 125 (volume of air required per minute). $125 \div 280 = 0.446$, or 0.45 sq. ft., which is equivalent to 64 sq. in. This is greater than a 9-in. pipe, so I use a 10-in. pipe.

9. What rule have you for the sum of the areas of all the air outlets of the furnace?

Wm. G. Snow.—The sum of the areas of all the air outlets of the furnace should be not less than 180 sq. in. to 1 sq. ft. of grate surface.

10. What rule have you for the area of registers?

Wm. G. Snow.—The area of registers naturally follows the determination of the pipe sizes. They should have a net area from 10 to 25 per cent. in excess of the area of the pipe with which they are connected.

J. P. Bird.—I make the area of the register 25 per cent. in excess of hot air pipe supplying it.

11. What preference have you as to the location of registers in different rooms?

Wm. G. Snow.—I believe in short pipes, and believe it better to locate the registers near the inner partitions, not too far from the furnace, in order that the pipes shall have a sharp pitch and not exceed, say, 16 ft. in length as a maximum. The hot air discharged through the registers first goes to the ceiling and then gradually descends around the outside walls and windows, being chilled and falling toward the floor by gravity.

J. P. Bird.—I prefer to have the registers in or near the inside walls, unless there is a fireplace in the room, and then prefer them to one side of the fireplace. The reason for doing this is that I find the air takes an upward course across the ceiling, so that if the register is not placed as suggested the floor will be cold.

12. What is your rule for area of foul air outlet from the house?

Wm. G. Snow.—In case foul air outlets are provided I would base their area on about a 15-minute air change in the room and a velocity of, say, 250 ft. per minute.

J. P. Bird.—For this I have no rule, but only use judgment as to what the room will be used for. To insure the entrance and circulation of warm air in every room I provide an ample supply of air to the furnace, and in the rooms on the side of the house exposed to the strong cold winds I use a larger pipe than would otherwise be necessary.

13. What method have you for insuring entrance and circulation of warm air in every room, particularly those on the side of the house exposed to the strongest cold winds?

Wm. G. Snow.—The furnace should be so located that the pipes will be shortest that lead to the rooms exposed to the coldest winds. Make sure the cold air box slide is sufficiently open to furnish air to fill all the pipes.

14. What is your opinion of warm air heating where a positive means of circulation is used, including both inlet and exit pipes for every room? Do you know of any examples, and where?

Wm. G. Snow.—I have used the positive system of circulation to heat small rooms remote from the furnace, placing a hood over the center of the furnace, connecting the supply pipe with same and bringing the return from the room to the casing of the furnace near the door. The hood mentioned is placed inside the regular furnace top, and insures the hottest air reaching the pipe connected with it. I would not recommend this system for an entire house, as it is human nature for people to save coal at the expense of other things that are really more important, and one of the chief advantages in the furnace heating system properly installed is that the house cannot be heated without supplying it with fresh air.

15. Design a system of heating by warm air for a 10-room house under the following conditions: The house fronts to the north and the prevailing cold winds are northwest; the lowest outside temperature is 20 degrees below zero. The library has a grate for a wood or coal fire. The house is well built; the windows in the north and the northwest rooms are double. All windows and doors are provided with weather strips and are as air tight as they can be. Show the location of the furnace and location and sizes of all pipes for fresh air, warm air, air circulation out of rooms and foul air exits, size and location of registers. The kitchen and laundry and the two unfinished rooms on the third floor are not supposed to be heated. Give a rule, a reason or formula for the adoption of every detail. (Accompanying plans showed an arrangement of four rooms upon the first floor, including a 12 x 14 ft. parlor and a 12 x 12 ft. library at the front, with a 6-ft. hall between them, a 14 x 15-ft. dining room at the rear of the library, and a 12½ x 14-ft. kitchen at the end of the hall; four bedrooms and bathroom upon the second floor, those over the library and parlor 12 x 16 ft. in size, one over the dining room 12 x 14 ft., and the bathroom and a 11½ x 12½-ft. bedroom over the kitchen; and upon the third or attic floor, two 12 x 13-ft. bedrooms and the remainder unfinished.)

Wm. G. Snow.—The heights of the several stories are not stated, but assuming the first to be 9 ft., the second 8½ ft., and the third 8 ft., I would proceed by computing the outside exposure, and to do this quickly would simply take the exposed walls of the first and second floors, assuming the non-heated portion to about offset the rooms on the third floor that are to be warmed. The total exposure would be about 2,700 sq. ft., which, according to the table on page 23 of "Furnace Heating," would require a furnace with a 28-in. pot.

I would compute the pipe sizes according to the table on page 38 of "Furnace Heating," and recommend locating the furnace nearly opposite the foot of the stairs to the cellar and under the northwest corner of the dining-room. If the house is to be heated to 70° when the outside temperature is 20° below zero, in case the air is taken from the outside, a furnace of about 46 per cent. greater capacity would be required than to heat the house in zero weather. (See page 51, "Furnace Heating.") It is hardly likely that in such severe weather it would be desired to burn sufficient coal to heat the house with outside air. I would therefore recommend a furnace having a 30-in. pot for the service mentioned.

J. P. Bird.—As near as I can make out by the plans, we have 3,400 sq. ft. of wall surface, and 476 sq. ft. of glass surface, or 1,326 sq. ft. of equivalent glass surface. The number of heat units lost per hour by transmission with the 90° difference in temperature inside and outside is $1{,}326 \times 104 = 137{,}704$. Basing the number of occupants at 10 persons and supplying 1,800 cu. ft. of air per hour per occupant, will require 18,000 cu. ft. of air. This amount represents the loss of heat by ventilation, $18{,}000 \times 1.25 = 22{,}500$ heat units. This makes a total of 160,204 heat units to be supplied by the heater per hour. Assuming one pound of coal will supply 8,000 heat units per hour to the air and a rate of combustion of five pounds of coal per sq. ft. of grate per hour, we shall require 4 sq. ft. of grate surface, or a heater with a 30-in. grate.

As no dimensions of the studding were given in the plans, I assume a 6-in. clearance. For the second floor I would use oval pipes, 5 x 15 in. in size, and for the third floor, 5 x 10 in. in size. Also I would heat two rooms with one pipe. Many engineers object to this plan, but I have installed several heaters on this arrangement and found them to give good satisfaction, with, I think, a saving of fuel. In all cases but the hall and third floor bedroom, I would heat the two rooms on one floor, for I have found when you heat one on the first and one on the second, the upper one has a tendency to rob the lower one. I would take my cold air supply from the west side and have a cold air chamber, which I think insures an even supply of air. (Accompanying plans showed the following sizes of registers: 12 x 14 in. in parlor and dining room, 12 x 12 in. in hall and library, 6 x 8 in. in 5½ x 6 ft. alcove off of dining room, 8 x 10-in. wall registers in all four bedrooms and the bathroom upon the second floor, and 8 x 8-in. wall registers in the two bedrooms upon the third floor. There are cold air ducts from registers in the main hall near the front door and in the kitchen near the rear entrance, 600 and 300 sq. in. in cross section respectively, and a 640 sq. in. duct to the cold air chamber.)

For ventilation the plans provide for a fireplace in the library, which I presume will use wood as a fuel. I have made tests on chimneys with wood fires in stoves and found an average difference between the temperature inside and outside of the chimney of 40°, but I think you will find that with an open fireplace the difference in temperature will be greatly reduced—say, 50 per cent.—which will make a difference of 20°. The chimney will be 30 ft. high, 78 sq. in. in area and with a 20° difference in temperature will remove about 144 cu. ft. of air per minute. In my opinion there will be ample ventilation on the first floor by the fireplace without the kitchen, which I would ventilate with a canopy or register behind the stove. As we have to remove 300 cu. ft. of air per minute, I should install a drum in the attic, so attached to the range flue as to utilize the waste heat from the kitchen range to effect a positive draft through the canopy. I have installed one such apparatus to ventilate a 10-room house, with canopy over the range connected with it, and it gives entire satisfaction.

16. If you live in a furnace heated house, can you furnish experimental data obtained from the heating system as follows: Temperatures in extreme cold weather, of air outdoors, and in different rooms; size of building; cubical contents of the rooms; exposure; number of pounds of coal burned in 12 hours daytime and 12 hours night; number of pounds burned per season; temperature of air entering furnace; temperature of warm air at several registers; velocity of air in flues and through the registers; area of inlet for cold air from outdoors; area of inlet from hall or other parts of the house.

Wm. G. Snow.—I have lived in furnace-heated houses and give the following experimental data:

With an outside temperature of plus 5° F. and cold air box wide open temperatures at first floor registers 116°, 114° and 146°; velocity, 418 to 465 ft.

On the second floor register temperatures were 100° to 127° and velocities 252 to 510 ft., the pipes being 6 to 8 in. in size, some of them of considerable length.

With an outside temperature of 24° temperatures at first floor registers 104° and 106°, velocities 306 to 335 ft.; on the second floor 95° temperature and 468 ft. velocity in a 6-in. pipe.

With an outside temperature of 34° velocity at first-floor register, 280 ft.; second-floor, 286 ft.

In a house having a floor plan 29 x 35 ft., the first and second floors heated in a run of 32 days with an average outside temperature of 27½° and furnace having an average firepot of practically 3 sq. ft., 2 lb. of coal per sq. ft. an hour were burned on each square foot of grate, average, for the entire 32 days of 24 hours each. The house was perfectly comfortable during this time and the furnace was coaled twice a day. During this run there was one cold day when the thermometer went to minus 5°. During these 24 hours 300 lb. of coal were burned at a rate of about 4 35/100 lb. per sq. ft. of grate per hour.

During a 20-day test in a similar house with a furnace having a 22-in. firepot, with an area of 2.64 sq. ft., average outside temperature 26.3°, the average rate of combustion was 1.84 lb. per sq. ft. an hour. During one cold day when the temperature went to 7° below zero and varied from that to 8° above, 258 lb. of coal were burned, an average of 4.07 lb. per sq. ft. an hour.

The house mentioned had about 1,700 sq. ft. of exposed wall and glass, the latter being about one-sixth the total exposure. This house required 10 to 11 tons per season to heat it. The first floor was 8½ ft. in the clear and the second floor 8 ft. During the cold day run, with an outside temperature of minus 8°, temperature taken at first-floor registers varied from 119° to 164° and on the second floor from 92° to 133°.

The average of several tests made on the quantity of air entering a furnace with a 24-in. firepot, the cold air box being about 80 per cent. of the area of the pipes, showed about 900 cu. ft. a minute supply. Tests made on furnaces having about a 24-in. firepot showed in a run of seven days, with outside temperature of 24°, 860 lb. of coal burned. The ashes weighed 90 lb. Another run of a week, with 23° outside temperature, showed 822 lb. burned, the ashes weighing 91 lb.

17. What are the principal faults that you have found in warm air heating installations when they have been incorrectly installed?

Wm. G. Snow.—Cold air box too small. Flues too shallow. Too little air space in furnace. Insufficient pitch to cellar pipes.

J. P. Bird.—Lack of air supply and poor workmanship in erecting, the latter including the pushing of pipes too far into boots and leaving large holes where the pipes are connected together. The apparatus is often entirely too small owing to the general inclination of customers to accept the lowest bidder, and there is also a lack of common intelligence in taking care of and running the furnace.

Steel Sheet Piling in a Mine Shaft.

Steel sheet piling has recently been successfully used in sinking a shaft for a coal mine through a stratum of water bearing sand and gravel near Auburn, Mich. The shaft as originally started in March, 1904, was 9 x 16 ft. in the clear. After it had been sunk through 50 ft. of clay a stratum of sand and gravel producing a very heavy flow of water was encountered. The shaft was carried down 30 ft. into this stratum by using a steel shoe on the bottom of the shaft timbering, and forcing the shoe down with 40 jack screws, the work on the shaft to this depth having required 4 months. The water, however, came in continually during the progress through water-bearing stratum, carrying with it large quantities of sand. When the shoe had penetrated 30 ft. into the sand and gravel stratum the surface of the ground around the mouth of the shaft caved in, owing to the undermining that had occurred by the washing away of the material below the clay.

Although the break in the ground surface broke the timbers in the shaft lining and threw the shaft out of line, two subsequent attempts were made to sink other shafts in the same manner with the steel shoe, but they were also unsuccessful. It was then decided to use the steel sheet piling made by the Friestedt Interlocking Channel Bar Co., and a fourth shaft of the same size as the previous ones was commenced. This shaft went through the 50-ft. stratum of clay at the top and was continued 15 ft. into the sand and gravel before the use of the steel piling was started. The piling was then set up in 5 and 10-ft. lengths in order to bring the steam driving hammer used in forcing it down underneath the braces in the shaft above. A standard Starr drilling machine and a hammer weighing about 1,600 lb. were used in driving the piles, the hammer having a 3-ft. stroke.

After the piling was fairly started there was never more than 5 ft. of it above the sand, so that the work was always near the bottom of the shaft. No trouble whatever was occasioned in driving the piling, other than a considerable delay made in changing the tackling so as to drive each plate. Each section that was set up was strengthened by breaking the joints with the 5 and 10-ft. lengths. In addition to this the sections were spliced with bolted plates and a band of copper placed between the ends of the iron. The splicing took but a short time and did not interfere in any way with the driving of the piles.

The piles were driven through 30 ft. of the sand and then 20 in. into bed rock below the latter. When the ends of the piles were securely driven into the rock, the remainder of the sand inside the space enclosed by them was removed. The shaft was timbered inside the piles as fast as the sand was taken out, and was finished 7 x 14 ft. in the clear. Two large steam pumps are being used in the shaft and the mine is producing 700 tons of coal a day.

The shaft was sunk for the Robert Gage Coal Co., of Bay City, Mich., under the direction of Mr. Chas. Coryell, vice-president and general manager, who furnished the information from which these notes were made. Mr. Coryell states that he is satisfied that the shaft could never have been sunk at the point where it was put down without the steel sheet piling, since as high as seven 6-in. streams of water were simultaneously coming from the sand, and the sand could not be prevented from flowing with the water when the timbering alone was used, making great cavities back of the shaft lining. He is also of the opinion that wherever the conditions are such that the piling cannot be used in the full length required it can be set up in sections the same as were used in this work and the sections fastened together with bolts and plates; and further, that where these splices are made the piling can be driven practically as easy as though it was in the full lengths.

Sewage Disposal Supervision in Illinois.

In 1903 the State Board of Health of Illinois conducted investigations of the water supplies of all cities of over 2,500 population in the State, and thereby gained excellent data for further sanitary work. In years past, a large number of cities and villages located on or near rivers and streams discharged their sewage directly into these streams. The rapid increase in the State's population, with the attendant increase in the volume of sewage, now renders this method of disposal thoroughly impracticable. The streams of the State which are also used for water supply are beginning to show a very considerable degree of contamination and pollution, and it is essential that greater protection be afforded them.

A large number of the smaller cities and villages in the State have up to this time discharged their sewage by means of loosely joined porous pipes, depending upon seepage for the disposal of the comparatively small volume of sewage, while other municipalities have cast their sewage into small streams which during a certain portion of the year do not have any appreciable volume of water. As the outlying districts have become more thickly populated, and as the volume of sewage has increased, these small streams and these loose porous pipes have become menaces to the public health, and it has been pretty well decided that the systems must be done away with.

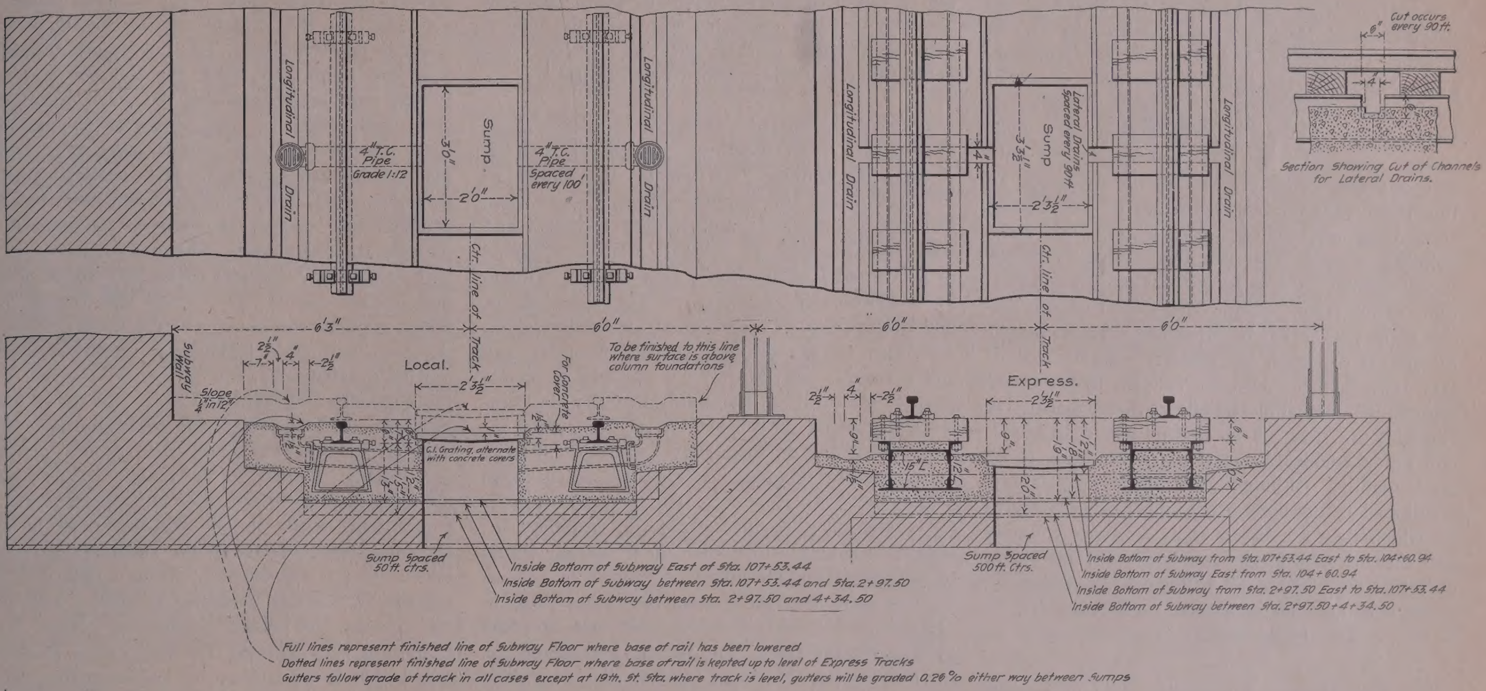
The State Board of Health has investigated the majority of septic tanks conducted by the municipalities of the State, and will continue to investigate such methods of sewage disposal to ascertain the conditions offered by them, the difficulties in their operation, and the circumstances under which they must frequently fail to produce good results. Having settled upon some satisfactory mode or modes of sewage disposal, the State Board of Health will ascertain the conditions in all of the various municipalities of the State and will then be prepared to recommend methods suitable to the individual municipality.

On account of the large amount of chemical and bacteriological laboratory work essential to the proper survey of the State, the State Board of Health has established a working relation with the State Water Survey, and will thereby be able to avail itself of the excellent laboratory facilities of the Water Survey at the State University at Urbana. This particular work is but preliminary to extended water investigations through which it is hoped that the sewage problems of the State will be simplified, water supplies more thoroughly protected, and the health of the people more effectively guarded.

The Painting Specifications adopted by Messrs. E. C. & R. M. Shankland for steelwork are intended to get rid of mill scale by rusting it loose. All material is thoroughly cleaned from all scale and rust before leaving the mill or shop. In riveted work all surfaces coming in contact are painted before being riveted together, and all surfaces not accessible for painting after erection are given two coats. Otherwise the steel has no protection until it has been erected, and by that time is pretty well covered with red rust. It is then cleaned with wire brushes and given two coats of good red lead paint, and the results are considered by Messrs. Shankland to be better than those of either oiling or painting accessible surfaces before erection.

The Track System of the Philadelphia Subway.

The general design of the subway of the Philadelphia Rapid Transit Co. was described in this journal on Feb. 25, 1905, when illustrations of its typical cross-sections were published. The first section was opened for regular use on Dec. 18, and on this portion of the line the width is 48½ ft. between side walls and the clear height above the rails is 14½ ft. Three intermediate lines of columns support the roof, which is designed to support the heaviest street traffic liable in any municipality. The roof is formed of concrete arches supported on I-beams, 5 ft. apart, placed across the subway; the side walls are of concrete, reinforced with steel rods, and the floor is of concrete. Terra cotta ducts, with manholes at frequent intervals, are built in the south wall, forming the conduits for the cables conducting electricity for the operation of the railway and lighting the subway and stations. The roof over its entire length is water-proofed with asphaltic mastic, 1 in. thick. The side walls are waterproofed where necessary with layers of burlap, coated with a compound consisting of the residuum from the refining of petroleum.


Longitudinal Drain
4" T.C. Pipe Grade 1:12
Sump
3'0"
2'0"
4" T.C. Pipe Spaced every 100'
Ctr. line of Track
Lateral Drains Spaced every 90 ft.
3'3½"
2'3½"
4"
Cut occurs every 90 ft.
6"
Section Showing Cut of Channels for Lateral Drains.
6'3"
6'0"
Subway Wall
Slope ¼" in 12"
Local.
For Concrete Cover
To be finished to this line where surface is above column foundations
C.I. Grating, alternate with concrete covers
Express.
15" C
12" C
Sump Spaced 50 ft. ctrs.
Sump Spaced 500 ft. Ctrs.
Inside Bottom of Subway East of Sta. 107+53.44
Inside Bottom of Subway between Sta. 107+53.44 and Sta. 2+97.50
Inside Bottom of Subway between Sta. 2+97.50 and 4+34.50
Inside Bottom of Subway from Sta. 107+53.44 East to Sta. 104+60.94
Inside Bottom of Subway East from Sta. 104+60.94
Inside Bottom of Subway from Sta. 2+97.50 East to Sta. 107+53.44
Inside Bottom of Subway between Sta. 2+97.50+4+34.50

Full lines represent finished line of Subway Floor where base of rail has been lowered
Dotted lines represent finished line of Subway Floor where base of rail is kepted up to level of Express Tracks
Gutters follow grade of track in all cases except at 19th. St. Sta. where track is level, gutters will be graded 0.26 % either way between Sumps

Track Construction for Local and Express Trains in Subway of Philadelphia Rapid Transit Co.

The conditions as to underdrainage permitted the placing of subdrains below the floor of the subway, by which any appreciable head of water against the side walls is prevented. This increased the dryness of the structure and permitted the omission of the waterproofing on the parts of the side walls where they have been made thick to promote facility of construction by the adopted method.

The underdrains include two lines of terra cotta pipe, one under each outside track, with laterals passing to the exterior of the side walls every 50 ft. The main drains lead to a pump well, where the water is discharged into a sewer by electrically driven centrifugal pumps regulated automatically by floats.

The track is quite novel, as no ballast is used. The object is to keep everything in a perfectly sanitary condition, and the entire roadbed can be washed down with the hose and drained through sumps which are placed at frequent intervals. Different forms of construction have been used in the express and in the local track. In the latter the rails are mounted on cast-iron chairs, which, with the rails, are completely embedded in concrete. This form of construction has been employed for a number of years on the surface lines of the company with excellent results. The chairs or yokes are spaced 5 ft. apart and are provided at their upper ends with guide lugs in which are adjusting screws. The inside ends of these screws bear against holding blocks which grip the foot of the rail so that the rail is adjustable to exact gauge by manipulating the screws. The rails are laid in a trench left in the concrete, which forms the rest of the roadbed. They are then aligned and the concrete is filled into the trench even with the top of the head of the rail on the outside and with the lower part of the head of the rail on the inside. In this way, if a rail has to be replaced, it is only necessary to remove the concrete in the trench. Sumps are provided in the local tracks at average distances of 50 ft.

On the express tracks, except at cross-overs, the rails are mounted directly on yellow pine blocks 6 in. x 24 in. x 10 in., to which they are attached by clips and screw spikes. These blocks are bolted to 12-in. channels, which are braced top and bottom at intervals by 15-in. channel braces. The longitudinal channels are set in concrete, as shown in the section on this page. The sumps on the express track are placed 500 ft. apart. One rail of each express track has been reserved for block signaling. The other rail is bonded with a Mayer & Englund protected bond, and the two return rails are cross-bonded. The return circuit is then reinforced by a 2,500,000-circ.-mil cable. The local tracks are laid with the standard zinc joint of the Philadelphia Rapid Transit Co. The rails for both tracks are 90-lb. Am. Soc. C. E. standard.

As the local tracks are to be used by trolley cars they are equipped with an overhead wire which is supported in a special flexible suspension. This consists of two 2-in. x ⅝-in. bars, which were set in the concrete roof of the tunnel while the latter was being built. To these bars are attached a 3-ft. 6-in. x 6-in. x 3-in. yellow pine timber, to which the wrought-iron brackets holding the flexible suspension are bolted. The double pull-off, which holds the trolley wire, is of the usual type, with two globe strain insulators, and is supported by a 5/16-in. steel span wire connecting the two brackets mentioned. The usual wooden guard plank is carried on the yellow pine timber above the trolley wire. A No. 0000 grooved trolley wire is used, and is held in a mechanical clip. A drawing of this suspension will be published in an early issue of this paper.

The express tracks and elevated structure will be equipped with a third-rail system. The type of third rail has not yet been selected. At present the express tracks will be equipped with the trolley system and will be used by the trolley cars until the elevated structure is completed.

An interesting feature of the subway construction is the arrangement for ventilation which has been provided at different points. Ventilation is secured not only by the openings into the street at the different passenger stations, but also by special chambers which are connected to stacks outside. Arrangements have been made at the base of these stacks for the installation of fans if necessary, but in most cases it is thought that the natural draft will be sufficient. There are three of these stacks on the section now completed, and shafts will be constructed on private property on the section which will next be opened.

The engineering for the Philadelphia subway was conducted directly by the engineering department of the Philadelphia Rapid Transit Co., and was in direct charge of W. S. Twining, chief engineer of the company. Mr. Twining's principal assistant in this work was C. M. Mills.

The Gas Turbine Problem cannot be solved until satisfactory information is obtained on four points, according to statements by Mr. R. M. Neilson before the Institution of Engineers and Shipbuilders of Scotland. These four points, which must be settled by experiment, are: 1, Losses in pneumatic compression to high pressures with reciprocating and rotary compressors or a combination of the two; 2, the expansion of hot gases in divergent nozzles; 3, the transference of heat from gases to metals at high temperatures, and particularly at very high velocities; 4, the oxidation of turbine blades when exposed to the action of air, steam, carbon dioxide and other gases at high temperatures. Until thorough experiments have been made on these four lines, he said, the chances of success of the gas turbine will be very much shrouded in darkness. It is to be hoped that this information will be forthcoming before long, and it will thus probably be known whether it is worth while expending money and energy on the gas turbine problem.

Book Notes.

The first volume of the report of the North Carolina Geological Survey is a sumptuously printed and illustrated quarto on "Corundum and the Peridotites of North Carolina," by Dr. Joseph Hyde Pratt and Prof. Joseph Volney Lewis. The portions of interest to the mineralogist and geologist relate mainly to the occurrence and cause of peridotites, but there are a number of chapters of direct practical application, in which the various applications of corundum in the arts, the methods of making corundum and emery wheels, and the mining and milling of corundum are discussed. The report is bound to be of much value in the development of the mineral resources of the State and as a contribution to the geological literature of the country. It is distributed from the Chapel Hill office of the State Geological Survey without other charge than 32 cents to pay postage.

A new edition, the tenth, of the handbook on "Hygiene and Public Health," written by Dr. B. Arthur Whitelegge and Dr. George Newman, gives a good perspective of the wide range of duties that are assigned to a medical officer of health in Great Britain. The authors are well-known authorities in that country on the subject, and they bring together in the 636 pages of this 16mo volume a large amount of information concerning air, meteorology, water, food, soil, buildings, schools, hospitals, the removal of refuse, the disposal of the dead, animal parasites, infection, disinfection, specific diseases, tropical diseases, the prevention of infectious diseases, medical officers of health and sanitary inspectors, sanitary law, factories and workshops, by-laws and regulations, and vital statistics. Some instructive statistics are given in an appendix and an excellent index enables all sections of the book to be used readily. Although the official regulations mentioned in the book are English, the principles on which they are based apply to every country, and the information in the book will be found useful in the office of all municipal health departments and municipal engineers. (Chicago, W. T. Keener & Co.; cloth, $1.75).

The State Bureau of Statistics, Agriculture and Immigration at Olympia, Wash., has issued a 256-page book on the "State of Washington in 1905." It is a general account of its natural, industrial and commercial resources, which have only recently begun to be properly appreciated. The semi-tropical climate of Southern California has drawn to that section of the Pacific Coast a large number of people, but the land about Puget Sound has for some reason been comparatively neglected. As a matter of fact, for an all-year residence there are very few parts of the United States which equal the northwest corner of the country, and none which surpass it. This volume is a well-illustrated and enthusiastically written account of the State's advantages as a place of residence. The first portion contains a number of general articles on educational institutions, soils, public lands, natural power, transportation, irrigation, lumbering, agriculture, dairying, mining and fisheries. The second portion contains a detailed description of the resources, climate and leading towns in each county, while the third portion of the book is a mass of statistical data which will answer most questions concerning what is actually being accomplished by the people of the State at the present time.

Engineers engaged in gas engine problems will welcome Prof. H. B. MacFarland's "Standard Reduction Factors for Gases." In reporting the results of gas engine tests it is necessary to reduce the quantity of gas consumed under test conditions to an equivalent amount under standard conditions of pressure and temperature. At the present time there are four of these standards, and the author's tables enable the results of the tests to be reduced to any or all of them. The formula on which the tables are based is $pv/t = PV/T$, too well known to require explanation. Other tables give the tension of water vapor in inches of mercury for both Fahrenheit and Centigrade degrees and in millimeters of mercury for Centigrade degrees, and the weight in grains of the moisteure in one cubic foot of saturated air for both the Fahrenheit and Centigrade scales. A table for changing pressures in inches of water into the corresponding barometric readings in millimeters and inches of mercury is also given. The last table is one of the most valuable in the book, for it gives factors for the ready solution of equations of the form $pv^n = PV^n$, where n has the values $10/9$, $4/3$, x, $1/x$, $x—1$, and $(x—1) \div x$. Readers whose work requires the occasional solution of such equations will find that this one table will make the book a valuable addition to their libraries. (New York, John Wiley & Sons; cloth, 64 pp., $1.50).

The first volume of a series of "National Engineering and Trade Lectures," which Mr. Ben H. Morgan is editing, "assisted by the Board of Trade, Colonial and Foreign Offices, Colonial and Foreign Governments and leading technical and trade institutions," is entitled "British Progress in Municipal Engineering." It is by Mr. William H. Maxwell, city engineer of Tunbridge Wells, and discusses road construction and maintenance, sewerage, sewage disposal, refuse cremation and water supply. Mr. Maxwell is not only acquainted with his subjects thoroughly through his regular professional duties, but has also acquired facility in writing on them from experience in preparing several engineering manuals which have found favor in England. The present work is essentially of a popular character, doubtless intended to supply information on municipal works to members of public boards who wish to acquire some general familiarity with the technical character of the works of which they are the custodians for the time. The text is well suited for the purpose, but the large number of illustrations of apparatus with which every public works official is familiar and the lists of manufacturers of such equipment look a little strange in a volume published in such an admirable form as this work. (Chicago, W. T. Keener & Co., boards, 8vo, $2.40.)

A thorough work on the propeller is being written by Mr. Albert Achenbach, of the Royal Academy of Marine Architecture and Engineering at Kiel, and the first volume has already appeared. It is devoted to a short historical account of the development of propellers and the practical methods of designing them. A volume on their construction and another on their theory and exact computation will be issued later. This first volume opens with a few pages on the geometric fundamentals of propeller drafting. This is followed by the historical sketch, which begins with the inventions of Smith in England and Ericsson, in the United States, thus omitting earlier inventors. The sketch is not comprehensive, a fact that the author points out, and is intended to outline only those improvements which he considers of most interest. The next two chapters discuss the pitch of the screw, and are followed by two on the laying out of the blades and the hub. The finishing up of the drawings for the shop is explained and finally the Zeise and Niki propellers are described. The text is illustrated by 25 good plates so bound into the book that they can be opened and the book then closed without interfering with their use, a convenience to the draftsman, for whom the book was particularly written. The author has prepared a thoroughly practical volume on a subject that has received only superficial attention in most books on marine engineering. (Kiel, Germany, Robert Cordes; cloth, 8vo, 10 marks).

It has been found in Great Britain just as in this country, that separate classes in mathematics should be formed for the benefit of engineering students, and a number of books have been prepared for their special use. The latest of these is Mr. Arthur Morley's "Mechanics for Engineers." It aims to present the elementary principles of the subject without abandoning the gravitational system of units. This is a desirable feature in a book for engineering students, for, with proper premises, the gravitational system is just as rational as that in which the poundal is the unit of force. The young men taking engineering courses in these days have to stretch their intellectual mechanism over such a wide range of subjects that the amount spread on any one is likely to be attenuated. For this reason the more they are taught to think for themselves along strictly engineering methods the more useful will their instruction be. No engineer in practical work ever thinks of a poundal save as a nightmare of his student days. It is perfectly proper to employ such units in physics, but why they are dragged into classes of embryo engineers it is difficult to understand. The author takes up in turn kinematics, the laws of motion, work, power and energy, motion in a circle and simple harmonic motion, statics, concurrent forces, friction, the statics of rigid bodies, the center of inertia and of gravity, moments of inertia, rotation and the elements of graphical statics. In many cases graphical methods of solving problems have been adopted in order to make the student familiar with them. Unless he is taught to use such methods readily he will lose an important aid in some of his work, and by adopting them he will become more confident in the accuracy of results which are not expressed in whole numbers. The practice of framing problems in such a way that the answers are whole numbers or simple fractions is a very bad one for engineering students, who ought to learn from the outset of their work to deal with the data of engineering in an engineering manner. Familiarity with the calculus is not necessary for using the book, but only algebra as far as the progressions, the elements of trigonometry and curve plotting. While the book is very satisfactory, special attention should be called to the great number of excellent problems given in it, which will be found of much utility by teachers of the subject. In an appendix there are also examples selected from examination papers set for the intermediate engineering science grade at London University, the associate member grade of the Institution of Civil Engineers, and the applied mechanics course of the Board of Education. (New York, Longmans, Green & Co.; cloth, 12mo, $1.20).

GOTHIC ARCHITECTURE IN ENGLAND. An Analysis of the Origin and Development of English Church Architecture from the Norman Conquest to the Dissolution of the Monasteries. By Francis Bond. London, B. T. Batsford, 8vo, 725 pp.

There are few engineering achievements which compare in interest with the problems of construction that were solved by the builders of Gothic churches. Until they began their work a building was essentially a roof considered as imposing vertical loading on the walls that carried it. The Gothic builders introduced the pointed arch and thus made it absolutely necessary to resist the horizontal thrust by some form of buttress. The pointed arch was the incentive, but the buttress was the important strucural feaure, without which the former would have been impracticable. It was a daring innovation and with it came many new details of construction which remain to this day, when Gothic architecture is no longer an ecclesiastical fad, models of architectural fitness.

Mr. Bond's book is probably the best work on the English Gothic architecture that has yet appeared. It is certainly the most satisfactory to the reader who desires details of construction rather than discussion on the artistic value of different edifices. The first portion describes the development of the style and gives a chronological history of the greater English churches. The second portion takes up in detail the elements of such buildings, plan, supports, arches, abutments and the like. It contains a great many illustrations of the same details from many churches, all drawn to the same scale, and in this way enables the reader to secure information of much structural importance which would require long search and much study to obtain from any other source. Many of these details are purely artistic, but there are others, notably that on abutments, which are wholly structural. It is for this reason that the book will be of special value to the engineering reader. It has received high praise as an architectural and historical treatise, and deserves equal commendation as an analysis of building achievements which must remain one of the great glories of the Anglo-Saxon race.

PRACTICAL CEMENT TESTING. By W. Purves Taylor. New York, The Myron C. Clark Publishing Co.; cloth, 8vo, 329 pp., $3.00.

This book is a contribution to engineering literature that deserves a warm welcome, for it is based on long experience and wide searching among the published and unpublished records of cement testing. Any material which is made from such diverse ingredients and is subject in use to such widely different working requirements manifestly demands very intelligent testing. At the present time cement is generally divided into "good" and "rejected" classes alone, but as experience is gained in its manufacturing minutiæ and its use there will unquestionably develop the same kind of gradation that exists in iron, steel and timber.

In order to ascertain just what are the properties of cement, it is necessary to test it, and the condition of testing practice until very recently was chaotic. While there were detailed specifications and rules for sampling and testing, the methods of manipulation were so varied that the results of tests by different laboratories and by engineers varied so widely between themeslves as to make them barely comparable. In other words, the product to be tested was of better quality than the testing. Owing to the recent work of the American Society for Testing Materials, American Society of Civil Engineers and other technical organizations, backed by the strong cooperation of the Association of American Portland Cement Manufacturers, the matter of specifications and testing is gradually being cleared up and the time is ripe for the publication of a book summarizing progress to date. This information is furnished in a very satisfactory way by Mr. Taylor.

The first three chapters on the classification of cements, their composition and physical constitution, and the different processes of manufacture now in use give in brief form the salient features of the subjects. The section on testing work does not begin until the fourth chapter is reached, when the author takes up inspection and sampling and the general features of cement testing. After this introduction the determinations of specific gravity, fineness, time of setting, tensile strength and soundness are described in much detail. A chapter of chemical analysis which follows was prepared in collaboration with Mr. Charles S. Reeve, a specialist in such work. The subject of approximate tests is discussed in one of the most interesting chapters in the book, its purpose being to explain methods of determining quickly the availability of a shipment for immediate use. The tests should be interpreted liberally and the material given the benefit of any doubt or held for more elaborate examination. Material positively unfit for service may always be discovered by their use. The three remaining chapters discuss the practical management of a testing laboratory, the properties of other varieties of cement than Portland, and specifications. The book contains appendices giving the Am. Soc. C. E. methods of testing, the analytical method endorsed by the New York Section of the Society for Chemical Industry, the standard specifications of the Am. Soc. Test. Mat., the Corps of Engineers of the U. S. Army, the British Engineering Standards Committee and the Can. Soc. C. E., and a bibliography of books on cement and concrete.

The chapters devoted to testing are very full of detail. While this is an advantage to the reader in search of information concerning all features of any class of tests, it may be questioned whether the author has been sufficiently detailed in his statements of preference between apparatus or methods of manipulation for a given purpose. A large proportion of the readers of this book will take it up for guidance rather than for general information, and will be particularly glad to know what methods are considered best at the Philadelphia municipal laboratory. This information can be ascertained by those who will read between the lines of some of the chapters and is clearly stated in other chapters, but nevertheless a somewhat more dogmatic position by the author would be an advantage to the reader. Of course, this would arouse more criticism, but nobody can write a really good book like this on cement or concrete without receiving a great deal of criticism, and a little more or less should not be a consideration of any weight.

Letters to the Editor.

SHRINKAGE OF ROAD MATERIALS.

SIR: We have an argument concerning shrinkage on macadam work where the foundation is an old macadamized road worn down to a rough and uneven surface. The first proposition was to even up the surface by filling with dirt and rolling the latting to a good solid surface. Afterwards this plan was changed so that the old surface was not disturbed, but the whole street filled with crushed stone of 1½ to 3 in. size for first layer. Stone screenings were washed in to fill all voids and the road then rolled with a 15-ton steam roller. Afterwards another layer of stone of ½ to 1½ in. size was placed, which was also covered with stone screenings, washed in to fill all voids and rolled to a good hard finished surface with a 15-ton steam roller, leaving 9 in. thickness on the most shallow places in the center of the street and where the street was previously worn down probably 14 or 16 in. depth in some places. The surface measurement is 6,000 sq. yd. and the stone used in construction was 2,650 cu. yd., all limestone of 2,600 lb. railway weight to the cubic yard. Will you kindly advise what percentage should the shrinkage be on that work, or how many cubic yards rolled stone as above would 2,650 cu. yd. loose stone make?

Yours very truly,

JOHN O. JONES.

Racine, Jan. 23.

[This inquiry was submitted to Mr. James Owen, M. Am. Soc. C. E., engineer of Essex County, N. J., where road construction has attained a high degree of perfection for many years. Mr. Owen states that his uniform rule for settlement in the consolidation of loose stone on roadways is to put on 4 in. of loose stone and roll it down to 3 in. This is based on a careful investigation made a number of years ago. It must be borne in mind that these figures relate to broken trap rock weighing about 3,100 lb. to the cubic yard, the pieces being of fairly uniform size and cubical shape. Limestone is sometimes flaky in its fracture and thus causes a variation from the figures given.]

CIVIL SERVICE QUESTIONS, BOARD OF WATER SUPPLY, NEW YORK.

SIR: In October and November, 1905, the Municipal Civil Service Commission held special examinations for the Board of Water Supply of the City of New York, for three grades of assistant engineers, for rodmen and for axemen. It is reported that 600 men presented themselves for the assistant engineer examinations, 800 for the rodmen, and 1,000 for the axemen, approximately. The questions have not been made public by the Civil Service Commission, but some of the young men who took the examinations wrote the questions down from memory after leaving the examination room. In this way I am able to give The Engineering Record a reasonably correct set of the questions for the assistant engineers. They were written on the days of the examinations by one of the candidates and reviewed by several others. As to order and wording they may differ slightly from the official questions, and parts of one or two questions may have been omitted.

GENERAL PAPER, 10 TO 11 A. M.

1. Extract the square root of 2030.40636.
2. Canal 125 ft. wide at top, 75 ft. wide at bottom, 10 ft. deep; drop of 40 ft. in 2,640 ft.; what is cu. ft. per second flow of water? $88 = C$.
3. Find the area of a triangle 50 ft., 60 ft., and 70 ft., on the sides.
4. What is the weight of a cast-iron pipe 4 ft. inside diameter, 1 in. thick and 12 ft. long, allowing 2½ per cent. increase for bell and spigot?
5. Change 35.2 in. per second to ft. per minute and miles per hour.

GENERAL PAPER, 11 A. M. TO 4 P. M.

1. What are the causes and means of prevention of failures in retaining walls?
2. Draw sketch of earth dam showing all details; water 25 ft. above earth and earth 20 ft. above rock.
3. Describe the several methods of driving wooden piles, and tell under what conditions each is used.
4. What methods are used in foundation construction over quicksand?
5. Describe the several methods of measuring the flow of streams.
6. What are the adjustments of (a) the transit, (b) the level, named in their order?
7. What is the prismoidal formula, and give an example of its use in finding the volume of an embankment or borrow pit?
8. In what way is Chezy's formula modified by Kutter's formula?
9. Name the watersheds which are possible sources of future supply for New York City, and the advantage or disadvantage of each.
10. How is concrete mixed in a "machine" mixer and how is it placed in position?
11. Explain what is meant by "rainfall" and "available water supply."
12. Tell how a drainage area is determined.
13. Explain a stadia survey and make out a set of notes showing what notes are taken in the field, leaving blank the ones computed in the office.

14 Explain briefly the methods used in tunneling (a) in solid rock, (b) in soft mud.

PAPER FOR ASSISTANT ENGINEER, MIDDLE GRADE, 10 A. M. TO 1 P. M.

1. State the theory of (a) water pressure, and (b) the action of a syphon.

2. Describe the method of making an accurate triangulation survey.

3. Design a steel water tower, 100 ft. high and 40 ft. in diameter.

4. Discuss the theoretical design of a masonry dam.

5. Give the essential construction details of a heavy masonry dam, (b) especially in regard to concrete.

6. Discuss the theoretical design of an arch to convey an aqueduct.

7. Show by sketches the methods of carrying a conduit across a marsh.

8. Give a monthly estimate in correct form for several items: (a) earth excavation with convenient waste; (b) rock excavation in great quantity; (c) heavy concrete, 1:3:5 mixture; (d) sheet piling left in place; (e) rubble masonry (heavy monumental).

9. State theory of rainfall in relation to wind and mountain ranges.

10. Describe the best method of finding the velocity of a stream.

11. Give essential points in the choice of a site for a large storage reservoir.

12. Describe method of preventing sedimentation in a storage reservoir.

13. Points to be considered in designing an open channel for a water supply.

14. Discuss evaporation from water surface, snow, ice and hard ground.

15. Specification for brick, mortar and construction for an aqueduct.

16. The essential points in the determination of the foundation of a masonry dam.

PAPER FOR ASSISTANT ENGINEER, HIGHEST GRADE; 1 TO 5 P. M.

1. How would you determine the availability of a watershed?

2. Design an aqueduct section with reinforced concrete.

3. Give a discussion of theoretical use of steel in reinforced concrete.

4. Discuss the consideration of a design of a large distributing reservoir similar to that proposed at Yonkers.

5. With the formula

$$q = cy \sqrt[4]{a^3 s}$$

find q for a culvert when $c = 75$, $y = 1.5$, $a =$ 5,000 acres, $s = 12$.

6. Assume a semi-circular arch and by sketches show the construction for a 50-ft. roadway.

7. Discuss the design of a large filtration plant for a large city.

8. Give co-efficient of friction in pipes. What influences this? Give the authority.

9. The time required to empty a storage reservoir.

Candidates for all three grades of assistant engineers were required to take the first of general papers on Oct. 12, and only those who had presented themselves for this examination were admitted to the second. A total mark of 70 per cent. is necessary in order to pass, the marking being based on both experience and questions. Men who pass the first examination will be entitled to appointment in the lowest grade, which corresponds approximately to the rank frequently designated as instrumentman or leveler, at an initial salary of $1,350. Those passing the second examination with marks of 80 or above will be entitled to appointment in the highest grade at an initial salary of $2,000 or more, while those passing with marks between 70 and 80 will be eligible for appointment to the intermediate grade, which corresponds approximately to the rank sometimes called transitman, at an initial salary of $1,650.

New Yorker.

Street Bounds.

Sir: No matter of more importance comes before the civil engineer than the location of the boundary lines of streets and highways. In 1848 the Massachusetts legislature passed a law requiring the termini and angles of all new highways to be marked with stone bounds, 6 in. square and 3 ft. long, 2 ft. at least to be below the surface, with a penalty of $50 per month for every month's neglect. Notwithstanding this severe penalty, until quite recently this had been overlooked, and numerous streets have been laid out in this and adjoining towns, which had no bounds set.

The initial bound of Emerson Street in this city, was described as follows: Commencing at a point in the southerly line of Winter Street, bearing S. 11° 22′ E. 11 Rds. 22 Lks. from the southwest corner of the Baptist Church, a building on the north side of Winter Street (but no monument was set). Then southeast to Merrimack Street (no bounds set on any part of the line). The street was to be 50 ft. wide easterly of this line. Years afterward it was found to be only 48 ft. wide and no one could tell where the street commenced or ended. The town of Haverhill was responsible for this job.

In 1851 the county commissioners located a part of Washington Street in Haverhill, commencing at Essex Street and running to a point in the eastern track of the Boston & Maine R. R., 25 ft. southwesterly from the southwest corner of the B. & M. Depot; but no person could tell years afterwards, what was the southwest corner of that building, and no monuments were set, thus showing that a heavy penalty was not sufficient to overcome an old custom.

For quite a number of years past, all the highways laid out by the City of Haverhill, and those laid out by the county of Essex, have been bounded by stone monuments. These have usually been made 6 in. square and 3 ft. long, but often they would be less than that at the bottom, and consequently in clayey soils they are frequently thrown nearly out of the ground by the action of the frost. In order to obviate this difficulty, we have recently relocated the boundary of a highway, in a neighboring town, and used churn-butted stone monuments, 3 ft. long, 5 x 5 in. at the top and not less than 5 x 7 in. at the bottom. In setting the first monuments used to mark street boundaries in this city, the line was fixed by a drill hole in the center of the monument.

This practice was found to be defective because, when a building was to be placed on the line of the street, the monument had to be removed. To avoid this difficulty, we have for the past thirty years set the stone bounds wholly within the street location. The description for record reads as follows: "Commencing at the southeasterly corner of a stone monument, set level with the surface of the sidewalk, at the junction of the south line of Main Street and the east line of School Street. Thence running S. 2° 22′ E. true meridian (as owing to the presence of electric wires, needle courses were useless) to the northeasterly corner of a stone monument, set to mark the northerly line of Spring Street. Thence same course 40 ft. across said Spring to the southeasterly corner of a stone monument."

These monuments are usually set from 8 to 10 in. above the surface of the ground, unless they chance to come in the traveled way, in which case they are set level with the surface.

It has become more or less fashionable of late, in the matter of locating new streets and relocating old ones, to make more or less use of curves of a specified radius. Curves should never be employed for marking the boundary lines of highways, or even for city streets, for the simple reason that a curve cannot be located on the ground. We know of an instance where a young engineer undertook the re-location of an old street by commencing at a stone monument and running thence northerly and westerly on a curve of given radius to another stone monument. Suppose either monument should be lost, how is it possible to re-locate it? His second course was a tangent to the curve he started on, but what do city governments or county commissioners know about tangents to a given curve? We are well aware of the fact that the ordinary practice is to run out a series of straight line chords, 100, 50 or perhaps as short as 20 ft., but this does not give us a curve. We see no possible way out of this dilemma except to fix the boundaries by a series of straight lines, thus ignoring curves altogether.

During the past season, the writer had occasion to re-locate some two and one-half miles of an old roadway, about two miles of which was bounded by long straight lines, the balance was more or less crooked, the longest straight line being some 1,200 ft. and the shortest 130 ft. Curves were tabooed to commence with, and every angle was marked by a stone monument, and on the longest lines, intermediate monuments were set, so that no distance between monuments exceeded 600 ft. and all the courses were referred to the true meridian, so that no controversy over the lines of this street ever need occur.

Another matter of altogether too much importance to be omitted here is the fact that in the location of new highways they should invariably be of uniform width, and in the re-location of old ones, this rule should be followed as far as possible. It has always been the practice in this county of Essex to locate streets and ways from one of the side lines, with only one exception. The original lines of the streets in one of our neighboring cities were fixed from the center line, and all the monuments buried. The inconvenience of this scheme is altogether too apparent for discussion.

Yours truly,

N. Spofford.

Haverhill, Jan. 20.

The Municipal Lighting Plant at Cumberland, Md., which is stated by newspaper reports to be supplying arc lights at $34.06 each, is really not doing quite so well, according to an article in the "Electrical World." The plant was placed in a small building adjoining the water-works, and by adding a few dollars to the wages of the water employees and hiring an electrician and trimmer, they were ready for business. The official figures are $7,879 for salaries and labor, $2,280 for fuel and supplies, $800 for interest and depreciation, or a total of $10,959. Deducting $2,000 for supplies on hand leaves $8,595, or $34.06 per lamp for 263 lamps. Against this showing must be placed various other factors. The plant cost $40,000 and is of antique design, so that 10 per cent. depreciation should be charged. Allowing for this depreciation, interest on $40,000, additional fuel, unconsidered labor, lamp renewals and repairs, will bring the actual cost, it is asserted, up to at least $59 per lamp. This plant was placed in operation in 1898 and was overloaded from the outset. They ran along for several years adding lights until the engine was unable to handle the load. An engineer looked the plant over and submitted a report advising throwing out the original plant and installing good machinery, capable of not only caring for the present but for the future as well, in addition to making provision for lighting the city buildings. Under these circumstances the plant cannot be considered a success.